A.I.A. NO. 12

Sweeney

MODERN APPLICATIONS OF

SHEET COPPER

IN BUILDING CONSTRUCTION

Modern Application of

SHEET COPPER in Building Construction

° A handbook for Architects and Sheet-Metal Contractors, Draftsmen and Artisans, Students and Apprentices. . . .

° Prepared under the direction of
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Copper & Brass Research Association

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FOREWORD

Prolonged building shortages, with the rise in construction costs that always occurs during such periods, focus the attention of building owners on materials and their relative worths over a long period of service. More important to the investor in real estate than capital expenditures are net annual operating profit and the long term yield from income-producing properties.

In the kind of real estate market that exists today the owner-investor gives preference to materials that, though initially highpriced, are durable and economical in maintenance costs.

Sheet copper for roofing, flashings and gutters offers to such an investor the plus values of permanence, workability and pleasing appearance. Because of these acknowledged attributes it warrants—and is usually given—prominent place in the cost-investment-yield analysis of a building not intended for resale.

For the same reasons, sheet copper is the preferred material for covering buildings intended for institutional, or eleemosynary, or religious, or monumental uses. First costs are high, but maintenance is low and there are no replacements.

"MODERN APPLICATION OF SHEET COPPER IN BUILDING CONSTRUCTION" has been written in the firm belief that, if income-producing real estate is to be a safe long term investment, quality materials and quality workmanship must be sensibly combined to assure those long-range economiës that minimize upkeep expenditures.

This book contains much new data, obtained from research into the characteristics of sheet copper and its behavior under the stresses caused by thermal changes. In general, this research indicates the use of hard, cold-rolled, or cornice temper copper instead of soft, hot-rolled, or roofing temper, and an increase in weight, or gage, in many places where 16-oz. had been considered heavy enough.

Perhaps there are no more vexing problems in the design and construction of a large building than those found in built-in gutters. Metal-lined gutters of large girth have given satisfaction for centuries on ancient buildings in Europe. Why, then, do some modern buildings in the United States have such unsatisfactory records? The answer, research shows, is primarily in the weight and temper of metal used. Experiments have demonstrated that shape of gutter and weight of sheet are important in preventing the incipience of the critical buckle that ends in a break. In rigid gutter linings there need be no failures.

No written treatment of this subject can be complete, and no attempt has been made to include all situations, alternate methods of construction, or special problems. When, as is inevitable, circumstances arise that are not covered herein, the Copper & Brass Research Association will be glad to advise as to the best current practice for meeting them.

Copper has one feature common to other good building materials. Proper application is a prime requisite for satisfactory service. Meticulous attention to detail is essential. Lack of understanding of, and failure to provide properly for, expansion and contraction cause nearly all the trouble with sheet-copper work that has come to the writer's attention in over 25 years of observation and study.

TO ARCHITECTS AND BUILDERS.—Copper is a good roofing material with an old and honorable record of enduring service. A good material deserves good design and good workmanship, both of which depend in large part

on a thorough understanding of copper as a live—not inert—material. Nothing but trouble can come from any effort to economize on first cost by skimping on workmanship. And the time to be sure design does not ask sheet-copper to do the impossible is before installation.

It is highly important that a competent and reliable sheet-metal firm be employed. A contract purchased solely on a price basis will be just that and nothing more, no matter how exacting the specifications may be.

TO SHEET-METAL WORKERS.—Upon the skill and craftsmanship of good mechanics depends the successful application of copper, or any other roofing material. That is why this book presents data covering only the basic principles of application. The knowledge gained from taking care of those special situations that arise on every job; from the exacting requirements of accurate shop work; and from talking with fellow craftsmen: will help, far more than anything we can print, to develop the ability to meet and master unusual conditions that means success.

TO OWNERS.—Even a roof as durable as one of copper needs maintenance. There should be periodic inspections and regular, frequent removal of the ash and soot that will collect in the gutters. Paper and other debris that can plug outlets must be removed. No building owner can afford to omit from his operating schedule a routine check of the condition of the roof over his property.

New York
August 1948

JOHN F. GOWEN

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Acknowledgment

The Copper & Brass Research Association wants to record here its deep appreciation of the assistance of many interested organizations, and of sheet-metal craftsmen, builders, architects, engineers, physicists and others whose experience and knowledge, both practical and theoretical, have been most helpful. To list all who have contributed to the collection and presentation of the data in this book would take far more space than is available.

Acknowledgment is also made here to various companies within the industry for access to their technical data on sheet copper, its characteristics and behavior in the laboratory and in service, and permission to use, without credit, by excerpt, abridgement and in other ways, material from their technical literature.

General Notes:

1. **DISTORTION OF DETAILS.** The distortion of the drawings, Plates I to XXXV, will be apparent. This has been done so that the application of the copper will be clear. In some cases drawings have been simplified by not showing all clearances to scale. The descriptive text facing the Plates is (and must always be so considered) an integral part of all details.

2. **OMISSION OF DETAILS.** In a few instances certain details that appear in one of the Figures on a Plate do not appear in similar drawings on the same and other Plates. The reason for such omissions is the desirability of maximum clarity of copper detail. The reader will be quick to note that the general information about installation that is set forth in Section 1, and the descriptive text that faces the Plates, cover these intentional deficiencies, if not by actual reference, at least by implication.

3. **BUILDING PAPER.** The use of building paper under all copper roofings and flashings is accepted, standard practice. For the sake of clarity in presenting details of application it has been omitted from the drawings.

4. **PATENTED DEVICES.** Although reference is made to them at various places in the text, practically no details of patented roofing, or flashings, or drainage devices have been shown. Such of these as reflect good design and represent quality products have the endorsement of this Association.

5. **NAILS, ETC.** Nails, screws, bolts, and all similar fastenings for copper work must be of copper, or of high copper-content alloy. The terms "copper", "brass" or "bronze" are used indiscriminately throughout this book to describe these fastenings. They, and the phrase "copper-alloy", should be taken as mutually inclusive.

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TEMPERS, WEIGHTS AND SIZES of Copper Sheet and Shapes for Various Uses

WHERE USED	REFERENCE	TEMPER AND WEIGHT IN OUNCES PER SQ. FT.		SIZE OF SHEET OR SHAPE IN INCHES	
	FIGURE NO. OR PAGE (P.)	COLD ROLLED	SOFT	WIDTH	LENGTH
Cant Strips	54, 56, 58, 85	16		Varies	96
Chimneys	111 to 114	16		—	—
Cleats:—Double Lock	10	16		2 (Min.)	3¾ (Min.)
—Single Lock	8	16		2 (Min.)	2½ (Min.)
Dormer Roofs	123, 124, 125	16 or 20		Varies	Varies
Dowels, Rods, Struts	119, 120, 121	16 or 20		—	—
Edge Strips	30, 35, 39, 53, 63, 73, 76–79, 85, 91, 95	16 to 32		Varies	96
Expansion Joints:—Covers	17, 93	16		—	—
—Floors	(P.) 137		16	Varies	96
—Gutters, Built-In	17, 86, 90, 92, 93	16		—	—
—Roofs	83		20	Varies	96
—Walls	83		16	Varies	96
Flashings:—Base, Narrow	111, 112, 114, 115, 123, 126	16		Varies	96
—Base, Wide	31, 36, 44, 49, 64–67, 69, 70, 72, 74, 78–80, 88, 89, 109, 117, 118	20		Varies	96
—Belt Courses, Stone	81	20		16	18
—Cap (Counter)	(See Base Flashings)	16		Varies	96
—Cavity Wall	82		10	Varies	72
—Copings	75 to 79	20		16	18
—Cornices, Stone	81	20		16	18
—Cornices, Wood	126	16		34	Varies
—Doors and Windows—Heads	127		3 (Membrane) or 6	Varies	60
—Jambs	127		3 (Membrane) or 6	Varies	60
—Sills	127	16		Varies	Varies
—Gable Ends	30, 35, 63	20		Varies	96
—Hips	50, 51, 60, 61	20		Varies	96
—Hips, Saddle	52	16		Varies	Varies
—Masonry Veneer	127		10	Varies	72
—Ridges	40, 50, 51	16		Varies	96
—Through-Wall—Concealed	81, 82		6 or 10	16 or 36 (Max.)	60 (Max.)
—Exposed, Narrow	80, 81		10	36 (Max.)	58 to 96
—Exposed, Wide	80, 81		16	Varies 36 (Max.)	58 to 96

TEMPERS, WEIGHTS AND SIZES of Copper Sheet and Shapes for Various Uses

WHERE USED	REFERENCE	TEMPER AND WEIGHT IN OUNCES PER SQ. FT.		SIZE OF SHEET OR SHAPE IN INCHES	
	FIGURE NO. OR PAGE (P.)	COLD-ROLLED	SOFT	WIDTH	LENGTH
Flashings:—Cont.					
Valleys, Closed—Slate or Tile	59	20		Varies	Varies
—Wood	59	16		Varies	Varies
Open—Slate or Tile	54, 57, 58	24		Varies	96
—Wood	54, 57, 58	16		Varies	96
Gravel Stops	62,108,125	16 and 20		Varies	96
Gutters:—Built-In—Apron	39, 87	16		Varies	96
—Lining	86 to 96	Varies		Varies	36 to 96
—Lock Strip	96	Varies		3 (Min.)	96
—Half-round—Hanging	133	16		Varies	120
—Molded (or Box)	84, 135	16		Varies	120
—Pole	85	16		Varies	48
Leaders (Conductors, Downspouts)	142	16		Varies	120
Leader Heads	143	16 or 20		—	—
Leader Straps	144	16		—	—
Louvres:—Frame Covering	(P.) 140		16	—	—
—Slats	(P.) 140	20		—	—
Outlets:—Gutter	101 to 106	16 to 24		—	—
—Roof	107 to 110	16 to 32		—	—
Roofing:—Batten Seam—20″ Pans	25 to 31	16		24	96
—24″ Pans	25 to 31	20		28	96
—Batten Covers	26	16		Varies	96
—Lock Strips	(P.) 36	16		2 (Min.)	96
—Valleys	29	16		Varies	96
—Standing Seam—Pan Method	34	16 or 20		20 or 24	48
—Roll Method	33	16 or 20		20 or 24	48
—Small Houses	(P.) 42	10		16 (Max.)	72
—Valleys	38	16		Varies	96
—Flat-Seam—Cleats	40 to 44	20		2 (Min.)	3½ (Min.)
—Sheets	40 to 44	20		16	18
—Corrugated—Sheets	45 to 49	20		27½	96
Scuppers	100, 109	20		—	—
Siding:—Standing Seam	36	20		34	Varies
—Flat-Seam	(P.) 48	20		18	Varies
—Corrugated	45, 46	16		26	96
Spandrels:—Wall Panels, Exterior	(P.) 54		20 to 24	Varies	Varies
Vents and Ventilators	115 to 118	16 or 20		—	—

The copper roof on Christ Church, Philadelphia, shown above, is now beginning its third century of satisfactory service. This roof is of standing seam construction, with unsoldered cross seams. The gage of the copper is approximately that of the present standard 20-ounce.

SECTION I—GENERAL

VARIOUS PROPERTIES OF COPPER

The first requirement of good building construction is stability; second only to this is the requirement that the materials used withstand the attack of the elements. These two axioms have as a corollary:—A building is only as good as the roof that covers it.

Nature goes about her destructive work slowly, starting at the weak points. When she combines her weapons of wind and rain, ice and snow, heat and lightning, erosion and corrosion, not many years elapse before poorly-built structures begin to crumble.

Copper has the necessary qualities to protect a structure against such attacks at its most vital point, the roof.

Copper combines durability, lightness in weight, ease of handling, beauty, and economy to such a marked degree, besides being fire-resistant, that it is a most practical, and one of the most widely used materials for roofing, flashings, gutters and downspouts.

The value of any product can be measured in large part by the degree of its public acceptance. On such important structures as Government buildings, public halls, hospitals, schools, churches and cathedrals — built for permanence—copper has found wide acceptance and use all over the world, and in all climates.

DURABILITY OF COPPER

Copper is one of the least chemically active of the commercial metals. This gives it high resistance to corrosion from air, water, and the weak acid solutions that develop in the atmosphere. It is rust-proof, and therein lies the key to the lasting qualities of a copper roof. Properly applied it provides insurance against costly repairs to the interior, and against maintenance expense. A copper roof is a high grade, long term investment.

Durability is especially important in flashings, gutters, and downspouts. Flashings are intended to prevent leakage at weak points such as joints, and around openings in exposed surfaces of structures. Gutters and downspouts must carry away the water shed by roof surfaces. These parts of the roof undergo severe service. When made of copper they stand the stress. Moreover, copper is fireproof. And, as its electrical conductivity is high, a copper roof, properly grounded, provides the best possible protection against lightning.

Numerous important buildings, as well as many fine residences, in the United States have copper roofs many years old; in Europe and Asia are other examples which have lasted for centuries. So far as is known the copper longest in continuous service is the cornice around the central opening of the dome of the Pantheon in Rome, which was placed during the reign of the Emperor Hadrian in 130 A.D., and was still in service up to World War II, a period of 1,812 years. Here follows a partial list of copper roofs still giving satisfactory service all over the world.

EXAMPLES OF COPPER ROOFING

Building	*Date*
Cathedral, Hildesheim, Germany	(See page 32)
Cathedral, Basle, Switzerland (Flashings)	1350
St. James's Palace, London, England	1520
St. Peter's, Rome, Italy (Flashings)	1550
Holy Ghost Church, Copenhagen, Denmark (Tower)	1582
Kronberg Castle, Elsinore, Denmark	1585
The Bourse, Copenhagen, Denmark	1624
Rosenborg Castle, Copenhagen, Denmark	1640
Drottningholm Palace, Lake Mälar, Sweden	1662
Town Church, Tilsit, Germany	1695
The Zwinger, Dresden, Germany	1711
St. Hedwig's Church, Berlin, Germany	1723
Christ Church, Philadelphia, Pa. (See facing page)	1737
The Naval Guard House, Copenhagen, Denmark (Tower)	1774
St. Peter's Church, Copenhagen, Denmark (Tower)	1756
Christians Church, Copenhagen, Denmark (Tower)	1769
Customs House, Dublin, Eire	1791
Cathedral of Notre Dame, Montreal, Canada	1824

EXAMPLES OF COPPER ROOFING (Continued)

Building	*Date*
United States Capitol, Washington, D. C. (Section of roof)	1827
Bodleian Library, Oxford, England	1830
State Capitol, Boston, Mass. (Dome)	1831
Bacon Residence, Madison, Ga.	1832
Chartres Cathedral, France	1836
State Capitol, Jackson, Miss.	1839
British Museum, London, England (Dome)	1840
York Minister, York, England	1842
Church of the Madeleine, Paris, France	1842
Bonsecours Church, Montreal, Canada	1848
St. James Cathedral, Montreal, Canada (Dome)	1852
Antioch College, Yellow Springs, Ohio	1862
Opera House, Paris, France	1865
State Capitol, Albany, N. Y.	1873

ECONOMY IN ITS USE

The first cost of copper is its only cost, if properly applied. Initially, it is more expensive than metals that rust, but such excess cost is trifling when compared with the total cost of the building. The long-run economy effected by the use of copper for roofing, flashings and gutters and down-spouts accrues through freedom from maintenance and replacement costs.

Copper's salvage value is an item to be considered by the prudent builder. In the event of the destruction or demolition of a building, copper always can be sold for a fair price.

ATTRACTIVE IN APPEARANCE

Nature acts as the decorator of copper. In time she forms an attractive green coating, known as "patina", that enhances the beauty of the structure and acts as a shield against deterioration. Copper requires no painting or other protective treatment.

The roof is more than a mere cover for the building. It bestows on it dignity, character and beauty; the nice balancing of roof design with roof color is an important factor in the harmonious blending of length, width and height. Happily, the age-old, time-tested methods of applying copper sheet as flat-lock seam, standing seam, and batten seam roofing all lend themselves admirably to certain classes of buildings.

EASE OF APPLICATION

Ductility and malleability are the general terms used to describe the capacity of a metal to be stretched without rupture. The first is usually applied to drawing, the second to hammering operations.

Copper is one of the most ductile of metals. This permits easy working, and makes it an ideal metal for roofing sheets. Through this inherent quality it can be shaped without difficulty to the contour of domes or cornices. as well as bent to form locks or valleys. Copper sheets can be obtained in hard or soft grades, and each has its place in sheet-metal work, as is explained hereinafter under "Tempers for Various Uses."

LIGHT IN WEIGHT

Copper's corrosion resistance makes it possible to use a thin sheet so it becomes one of the lightest of roofs, thus eliminating heavy supporting structures. The weights of various roofing materials are as follows:

Material	*Approx. Weight of 100 Sq. Ft. Laid*
Clay Shingle Tile	1000 – 2000 lbs.
Clay Spanish Tile	800 – 1500 "
Slate	600 – 1600 "
Hard Lead Sheet (about ⅛")	600 – 800 "
Felt and Gravel (Slag 100 lbs. less)	550 – 650 "
Asbestos Shingles	265 – 650 "
Asphalt Shingles	130 – 325 "
Wood Shingles	200 – 300 "
22 g. Galv. Iron (Corrugated)	175 "
16-oz. Copper	116 – 145 "
26 g. Galv. Iron (Standing Seam)	100 – 125 "
Tinned Steel	65 – 100 "
Aluminum	35 – 60 "

TEMPER OF COPPER SHEETS — NOMENCLATURE

Copper sheets are produced in varying degrees of temper, or hardness. Usage has established two of these as best suited for general sheet-metal purposes in building construction. The rolling mills and the sheet-metal trade have come to know them as "soft", and "cold-rolled" copper; and it is common practice to so designate the sheets

in specifying or ordering. As these terms have sometimes caused misunderstanding at the rolling mill, because, not knowing the ultimate use of sheets thus described, it does not know *how* "soft" or "hard" they should be, it is recommended that, *when dealing directly with the manufacturer,* the desired temper be specified as "soft (roofing temper)", and "cold-rolled (cornice temper)". Manufacturers know exactly what degree of hardness or softness these tempers require.

To bring about a uniform nomenclature in the building industry for copper sheet used in building, the trade and the architectural profession are urged to use the following terms:

Instead of	*Use*
Soft-rolled Hot-rolled Roofing Temper	SOFT
Hard Hard-rolled Cornice Temper	COLD-ROLLED

TEMPERS FOR VARIOUS USES

In general COLD-ROLLED copper is recommended for all sheet-metal work in building construction. Soft copper should be used *only* for standing and batten seam roofing, and for caps and certain through-wall flashings. The technical staffs of the producers of sheet copper should be consulted in all cases where the use of soft copper is contemplated.

The old idea, still widely held, that SOFT copper is suitable for all roofing and flashing work regardless of size or proportions, has been quite thoroughly discredited. Extensive research by the Association and its component members has given new insight into the behavior of sheet copper under thermal changes, and has demonstrated beyond a doubt that COLD-ROLLED sheet offers far more resistence than does SOFT to the stresses induced by expansion and contraction.

WEIGHTS AND GAGES

Copper sheets are made in all weights and gages up to a thickness of $\frac{3}{16}$ inch. Thicknesses greater than that usually are classed as plates. The gage of sheet copper is defined by the ounce weight per square foot; "16-oz. Copper" means copper weighing 16 ounces per sq. ft. Page 143 gives a table of weights and gages.

In the past it has been usual practice, wherever copper sheet was to be used in a building, to specify 16-oz. copper without regard to the stress and exposure to which it was to be subjected. Examination and measurement of many installations during recent years have demonstrated that as conditions of usage and exposure show wide variations, the weight of sheet to be used is governed by the type of service required of it and the method of installation.

Sixteen-ounce copper is the minimum weight suitable for exposed flashings, formed gutters, leaders, and for roofing work on large structures. Installations that have lasted through the years under severe service conditions are heavier, and present-day conditions in and near our populous industrial cities, with soot and gas-laden atmospheres, are much more rigorous than those of the past. Under conditions of unusual exposure or heavy duty, where corrosion or erosion, or both, are likely to be severe, the thickness of the sheets must be increased. On roofs of heavy slates or tiles, for instance, 20-oz. copper flashings are recommended.

And, as is demonstrated on page 86, the weight of copper used in a built-in gutter is related directly to its length and width.

The run-off from a glass skylight inhibits the formation of the natural protective coating (patina) that would normally form on copper. With an all-copper or non-ferrous skylight construction, this makes no material difference. If, however, the skylight frame is partly ferrous, iron salts washing down will cause discoloration, and possibly corrosion. To meet such a condition heavier gage metal should be used at such points, or the run-off should be collected in a separate gutter so that it will not drain on to the main roof area.

In suburban or rural locations, where the atmosphere is free of acids, copper lighter than 16-oz. has been advocated, and is being used, for sloping roofs of residences and for small roof areas. Even in such instances, however, we recommend that 16-oz. copper be used for leaders and gutters.

Nothing lighter than 20-oz. copper should be used for flat areas, which require soldered flat-seam construction, and where conditions are more severe than on steep slopes.

There are bound to be slight variations in the thickness, and correspondingly in the weight, of rolled metal sheets or strips. The accepted tolerance practice is given on page 142. Further data on the physical properties of copper will be found in Section 7 on page 142.

DISSIMILAR METALS—ELECTROLYSIS

Dissimilar metals, when in contact in the presence of an electrolyte, such as water containing very small amounts of acid, set up a galvanic action that results in the deterioration of one of them. The following table lists the more common commercial metals according to what is known as the electro-chemical series:

1. Aluminum
2. Zinc
3. Steel
4. Iron
5. Nickel
6. Tin
7. Lead
8. Copper

When any two metals in this list are in contact, with an electrolyte present, the one with the lower number is corroded. For example, if number 3 and number 8 are in contact, the steel will be corroded. This phenomenon must be kept in mind wherever two or more metals are used in construction; for the electrolyte may be formed from water or moisture-creating solutions from ingredients in the atmosphere.

Such galvanic action, for the purpose of this discussion, increases as the metals are farther apart in the electrochemical series. Hence, if iron (or steel) and copper are in contact where there is moisture, the ferrous metal is corroded. If water passes over copper onto iron, the latter corrodes rapidly. For instance, rain water draining from a copper roof into a galvanized iron (steel) gutter is likely to eat through the ferrous metal in a few months. Obviously in such case insulating the gutter from the roof will not help. However, insulation between dissimilar metals that otherwise would be in contact will prevent the galvanic action that goes on under such conditions.

A similar tendency exists between lead or tin and copper, but here the galvanic potential is so much less that no injurious results are produced, especially if only rain water is the electrolyte.

Only copper, or high-copper alloys, should be used in contact with copper work, as, for instance, nails, screws, and fastenings. If the use of other metals is unavoidable, any possibility of galvanic action should be guarded against by proper insulation. This problem arises most commonly when ferrous metals are involved, and insulators for such cases are listed below in the order of recommended practice:

1. Asbestos—frequently used in skylight construction;
2. Strips of sheet lead between the metals;
3. Heavy tinning of the ferrous metal;
4. Good quality, moisture-proof, building paper or felt:
5. Heavy coat of asphalt paint.

EXPANSION AND CONTRACTION

Copper expands and contracts more than some building materials, but not as much as others.

Following are listed the linear movements, for a 150° F. change in temperature, of eight-foot sheets of the principal metals used in building work:

Metal	*Inches*	*About*
Steel—soft	0.0878	5/64
Iron	0.0965	6/64
Steel—hard	0.1051	7/64
Monel Metal	0.1104	7/64
COPPER	0.1411	9/64
Aluminum	0.1843	12/64
Lead	0.2331	15/64
Zinc—rolled	0.2492	16/64

Because of the relative values of the metals' coefficients of expansion, for any given temperature variation there will be more movement in copper than in iron, steel or monel, and less than in aluminum, lead or zinc.

Temperature conditions at the time the work is done must be considered in allowing for expansion and contraction. Metal laid during warm weather needs little room for expansion; but it does require ample provision for the contraction that comes with cold weather. The reverse is true, of course, of work done in cold weather, when ample room for expansion must be provided.

Sheet-copper work will not fail from expansion and contraction if it is properly installed. Individual installations present individual problems for taking care of such movement. Many of these are described in the details that follow in the plates, and the descriptive text accompanying them.

CHANGES IN TEMPERATURE

To obtain data on the temperature changes to be expected in sheet-copper work an investigation was undertaken by the Bureau of Standards at Washington, D. C. Continuous records of the temperature of a copper roof for about one year made it possible to determine the maximum and minimum reached and also the rate of change. Simultaneous air temperatures were measured during a part of the same period.

The results showed that during the night the roof temperature remained quite uniform. It dropped slowly to a minimum which occurred nearly always at 5 oclock in the morning. While the sun was down, the roof temperature ran slightly less than the air temperature. This effect, noticeable on all clear nights, was due to the radiation of heat from the copper to the atmosphere. This undercooling averaged about 10° F. and a maximum of 16° was obtained.

At sunrise, the roof temperature began to rise sharply, at first in a fairly uniform manner; but as the sun got higher small fluctuations of four or five degrees began to appear. The effect of occasional clouds was very marked in causing a drop in the roof temperature, even though the air temperature was not perceptibly affected. The record for the afternoon was similar to that of the morning but, of course, with decreasing temperatures. The difference between roof and air temperatures (superheat) when the sun was shining, was very large.

On rainy days, or days when the sun was completely obscured by heavy clouds, the record was similar to that at night except that the roof temperature virtually was the same as that of the air.

For design purposes the maximum fluctuations in the roof temperature throughout the year must be considered.

The summarized data for the investigations in Washington are as follows:

Max. roof temp.	(July 22)	147°
Corresponding air temp.		103°
Min. roof temp.	(Jan. 29)	10°
Corresponding air temp.		11°
Max. superheat	(April 10)	58°
Max. under-cooling	(June 15)	16°
Max. rate of change in 6 hrs.		0.2° per min.
Max. rate of change in 30 min.		1.5° per min.
Max. rate of change in 5 min.		7.2° per min.
Max. aver. daily range (month) of roof	(May, 1926)	63°
Corresponding aver. daily temp. range		18°

The roof studied, that of the National Museum, had been in service long enough to develop a uniform green patina, so the results obtained should be fairly representative of the temperatures to be expected on the average copper roof. New copper would have a lower coefficient of absorption and a higher coefficient of reflection, and hence would show a lower range of temperatures.

Radiation emitted from the copper at night seems to be nearly constant during the year, the average undercooling being about 10° F. on clear nights.

Assuming a maximum possible superheat of 75° and an air temperature of 105°, it appears that under exceptional circumstances a copper roof may reach a temperature of 180° F. The recorded maximum of 147° was on an exceptionally hot day. Over most of the United States a temperature of 150° will rarely be exceeded.

It is important to stress again the necessity of taking into consideration the roof temperature at the time the roof is laid. If the metal is placed in hot weather, provision must be made for contraction resulting from a change to the coldest air temperature expected in the winter. If the metal is applied in cold weather opposite conditions prevail, and expansion movement must be calculated by adding from 50° to 75° to the maximum air temperature which develops during the summer.

THERMAL MOVEMENT AS A FACTOR IN DESIGN

The designer of a structure must allow for the changes in shape that result from changes in temperature. If he fails to do so, tremendous forces will develop. Anyone who has seen a concrete pavement shattered by the heat of a summer day will appreciate the violence of such reactions.

The forces deriving from thermal changes can be demonstrated by examining the behavior of copper sheet, soft and cold-rolled, within a temperature range of 170° F.—from 20° below to 100° above—plus a superheat of 50°. The physical characteristics of copper are, for—

ELECTROLYTIC SHEET	SOFT	COLD-ROLLED
Elastic Limit (Yield Strength; 0.5% Extension under Load)—Lbs. Per Sq. In.	10,000	28,000
Modulus of Elasticity—Lbs. Per Sq. In.	17,000,000	
Coefficient of Expansion	0.0000098	

Through a temperature change of 170° F. such copper would behave thus:—

Elongation (Expansion) Per Unit of Length	0.001666
Equivalent Stress in Lbs. Per Sq. In.	28,320

If a flat surface were covered with copper sheet laid at 90° F. and so fastened as to prevent any movement through a temperature range of from 20° below to 150° above, the metal would undergo stresses totaling 28,320 p.s.i., ranging from 9,990 p.s.i. compression to 18,330 p.s.i. tension. Obviously then, the elastic limit of soft copper would be exceeded by 83% (under tension), while cold-rolled copper would be stressed only from 36% to 67% of its elastic limit.

Under such conditions soft copper would rupture; cold-rolled copper would absorb both tension and compression stresses. (See also page 24.)

EROSION OF METAL

Erosion, or the mechanical wearing away of metal by moving water and whatever that water may carry, is accelerated by water impinging on the metal rather than merely flowing over or past it. It is distinctly advisable, in planning roof drainage, to avoid designs calling for water falling in quantities upon copper areas, such as from a dormer eave to a roof below. Gutters and downspouts should be provided to carry the flow down to the roof. Erosion should be considered in choosing the weight of metal at special locations.

SEAMS AND OTHER ESSENTIALS

SOLDER, SOLDERING AND PRE-TINNING

Soldering and soldered seams should be avoided where possible. There are many places in sheet-copper work, however, where solder is necessary, and in these the joints must be tight and strong.

Good soldering depends in great measure on the care

exercised in cleaning the surfaces, for solder will not adhere to a dirty or greasy surface. Fluxes are used to remove and prevent the further formation of oxide, as solder will not adhere to an oxidized surface.

Joints to be soldered should be closely fitted together. It is wrong to assume that a large amount of solder on top of, or alongside, a seam will give a strong joint. The results of actual tensile tests, made by the Bureau of Standards* on 14-, 16-, 18-, and 20-oz. copper show that a large increase in the width of the solder band, corresponding to a great increase in the amount of solder used, results in only a small increase in strength. The piling up of heavy wide bands of solder on flat-lock seams to increase their strength is not worth while.

Soldering should be done slowly with properly heated coppers, so as to heat the seam thoroughly and insure a completely sweated joint. It is most important that locked seams be filled entirely with solder. In lap seams a thin film of solder with proper adhesion between the copper sheets gives a strong joint.

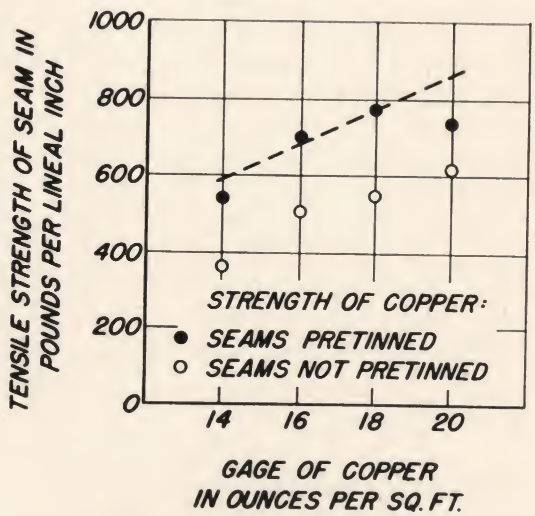


FIG. 1—EFFECT OF PRE-TINNING ON STRENGTH OF ONE-HALF INCH FLAT-LOCK SEAMS

The edges of sheets to be soldered must be tinned before soldering, for a width at least ½ inch wider than the finished seam. Otherwise concealed surfaces will not adhere, and seams will not develop the strength of the sheets, as in **Fig. 1**, which gives the results of tensile tests on flat-lock seams. Pre-tinning permits complete union between all the layers of copper in the seam, whereas in the flat-lock seam made without pre-tinning only two of the layers are completely joined. (See **Fig. 2.**)

Either new block tin or "50-50" solder (half lead, half tin) should be used for pre-tinning. Pre-tinning is equally effective whether solder or tin is used. The sheets should be dipped in the molten tin or solder in the mill or the shop rather than tinned with a soldering copper on the job, for a smooth, clean, uniformly thick coating can be best obtained this way.

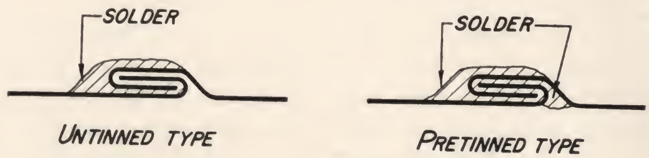


FIG. 2—SOLDERED FLAT-LOCK SEAMS

Tinning can be done at the rolling mills. Where it is possible to estimate in advance the amount of tinning necessary it often is advantageous to have the work done there as it insures even distribution. Where tinning on the job is unavoidable, heavy coppers are essential for satisfactory results. The same flux is used for tinning as for soldering.

FLUXES FOR SOLDERING

Resin is recommended as a flux. It is harmless to the metal, and makes seams as strong as those made with acid flux. Rosin takes more labor, but it is safe. There are some objections to its use, such as sloping roofs and windy days. Under these conditions it is much easier to use killed acid. However, rosin can be kept in place by "burning" it on with a small soldering copper just hot enough to melt the rosin. Powdered rosin in gasoline can also be used.

Killed acid is commonly used as a flux and, in the majority of cases, successfully. Nevertheless, it should be avoided as there is danger of injury to the sheets.

If acid is used, its proper preparation is of great importance. The acid used is hydrochloric (muriatic). Pieces of zinc are added to the acid until there is no more chemical action and the liquid is inert; the acid is then properly killed. If this killing is done hastily the acid is used in a still active state and attacks the copper. Pitting ensues and the work is spoiled. The acid to be used for an entire job should be prepared several days before the work starts and allowed to stand. Even with these precautions all work should be carefully cleaned when finished (see page 28). Moreover, raw acid should never be taken from the shop to the job. There is too much danger of spilling or spattering it, or of mistaking it for killed acid and using it for a flux.

In repair work, involving weathered and perhaps dirty material, it sometimes is impossible to use a rosin flux. Unkilled hydrochloric or muriatic acid then is necessary for cleaning surfaces prior to soldering. This should be thoroughly washed off, and then rosin used as a flux.

Should acid be used, the soldering should be washed thoroughly to remove the possibility of further action by acid that would damage the sheets or cause staining. To

* "Seams for Copper Roofing", U. S. Bureau of Standards Research Paper No. 216; 1930.

neutralize any acid present, use a solution of soap and 5 to 10% washing soda to wash the seams and, preferably, the entire area where soldering has been.

COPPERS FOR SOLDERING

Proper soldering coppers are essential for making tight seams. They should be of heavy, blunt-end type to hold the heat and spread the solder. They should be moved slowly so as to heat the sheets thoroughly and amalgamate the tinning with the solder sweated into the seam.

Soldering coppers should be tinned before use, and care must be used to avoid burning either the tinning or the copper. They must be hot, but not overheated.

For upright seams pointed soldering coppers should not be used because there is not sufficient heat in the point. In such cases, use a flat chisel-point pattern, weighing not less than six pounds to the pair. For flat seams use a blunt square-end type of copper weighing not less than ten pounds to the pair.

THE LAP SEAM

The lap seam, illustrated in **Fig. 3**, is the simplest of the seams used in roofing work. It can be soldered, or riveted, or left loose to permit free movement, as in flashing and valley work. Where the loose lap seam is used on slopes, the amount of the lap, depending on the pitch, is important. In this connection see the discussion of valleys on page 60.

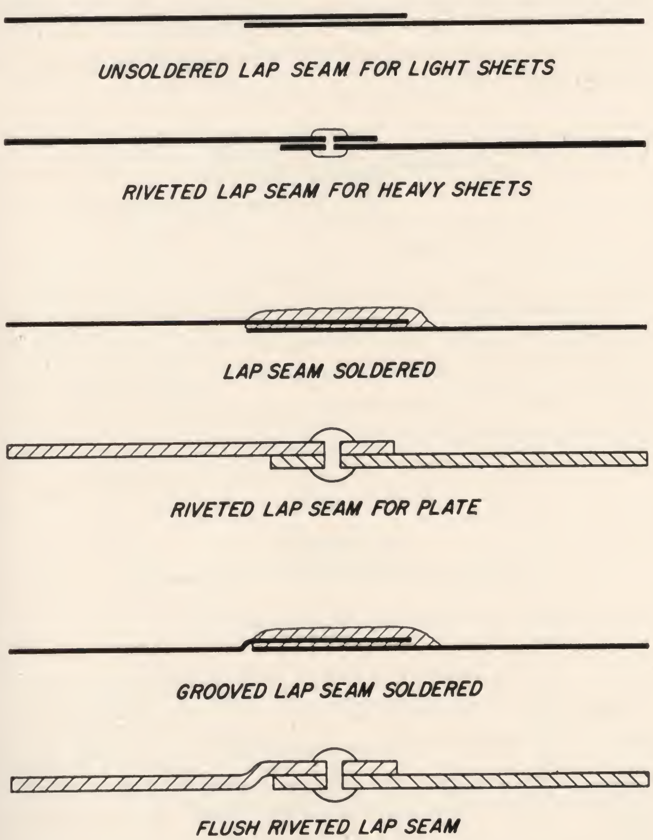


Fig. 3—Lap Seams

Under tensile stresses of short duration ¾-inch soldered lap seams are as strong as the copper sheet itself on weights up to 20-oz. One-inch soldered seams are equally as strong on weights up to 24-oz. In actual practice it is usual to allow a liberal factor of safety by adding ¼-inch or more to the minimum safe width.

The edges of sheets that are to be lapped and soldered should be pre-tinned a minimum of ½ inch wider than the finished seam.

Cracks sometimes appear in the solder of seams that have been satisfactory for many years. It has been long known that solder will flow or "creep" under the continued stress of a load not great enough to cause quick failure. If the load is sufficiently heavy "creeping" will continue until failure occurs.

The strength of a soldered seam in tension depends, then, not on the load it can sustain temporarily, but on the maximum stress it can stand continuously. The ideal installation would be such that soldered seams are not subject to stresses of more than a few minutes duration. But as this is impossible in practice, it becomes necessary for both designer and installer to take into account the fact that solder subjected to long-continued stresses eventually will fail.

Tests (see footnote, page 16) show that the maximum safe sustained load for lap seams is about 350 pounds per square inch of seam, and that this is independent of seam width and copper thickness. The curve in **Fig. 4** shows that soldered lap seams under a continuing tensile stress of 360 p.s.i. of seam failed after 86 days, and that loads of 350 p.s.i. were sustained for 212 days, the full duration of the tests.

To determine the safe width of a soldered lap seam consider a one-inch length. The cross-sectional area of copper thus is one times the thickness in inches, and this area times the unit stress gives the total stress on the one-inch length of seam. This total divided by 350 gives the required area of the seam, which, being one inch long, is numerically equal to the required seam width.

An example will show the application of this. Suppose 16-oz. (0.0216 in. thick) copper sheets are to be joined by lap seams. The heat of soldering will completely anneal these sheets, thus reducing the elastic limit to 10,000 p.s.i. So a one-inch length of seam will sustain a maximum stress of $10{,}000 \times 0.0126 \times 1$, or 216 pounds. The amount of lap necessary is, therefore, 216 divided by 350, or 0.616 ins. Thus a ⅝-inch seam will develop the full strength of the sheet.

This is a simple way to compute the strength of lap seams, provided one remembers that it does not apply to

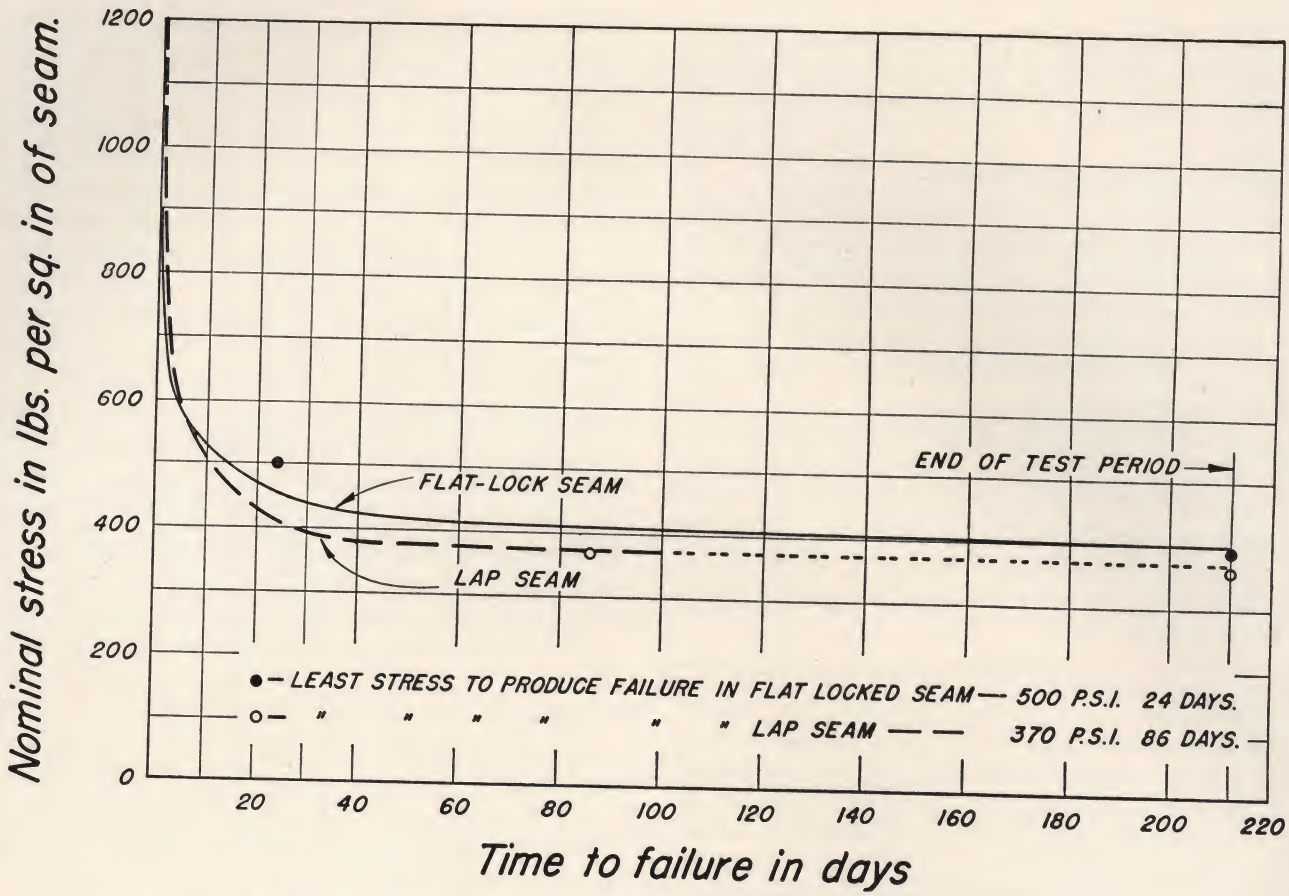


Fig. 4—Results of Prolonged Load Tests on Lap and Flat-Lock Seams from 1/4-Inch to 1/2-Inch Wide Made with 14-, 16-, 18- and 20-Oz. Copper Sheet

seams much wider than one inch (computed), and that the sheets at the line of solder have only the tensile strength of fully-annealed copper.

Actually on roofs and in gutters copper seldom reaches a state of prolonged stress, for the sheets, being able to move, only infrequently develop stresses exceeding the strength of the solder. The tests (**Fig. 4**) show that a stress of better than 800 p.s.i. of seam can be sustained for 60 hours. It would be a most unusual spell of extremely cold weather that would bring about such a condition.

Soldered lap seams should never be used when the full strength of cold-rolled copper is a factor. Under such circumstances rivets and brazing will best meet stress requirements; solder would serve merely to prevent leaks.

Riveted lap seams are also illustrated in **Fig. 3**. These are used mainly for plate work, although occasionally roofing accessories such as tanks, cornices, skylights, etc., require this type.

THE HOOK OR FLAT-LOCK SEAM

The hook seam is the type most widely used in copper work, and is illustrated in **Fig. 5**. It is made by turning the edges of adjoining sheets in opposite directions, hooking them together and dressing down the joint with a mallet. The flat-lock seam (sometimes called the groove-lock seam) of roofing parlance, is a slight variation of the hook seam, as shown in **Fig. 6**. It can be developed from the hook seam by the use of a grooving iron.

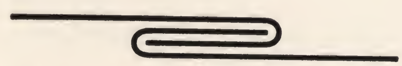


Fig. 5—Common Lock, or Hook, Seam

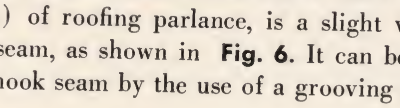


Fig. 6—Flat-Lock Seam

It is often necessary, however, to make flat-lock seams where there is not sufficient room to hook the sheets together. The seam then is developed as shown in **Fig. 7** as follows: **(1)** Tin edges of sheets; **(2)** Bend edges at right angles; **(3)** Set sheet with the short bend (A) in place; **(4)** Set second sheet (B) in position; **(5)** Turn edge of sheet (B) 180° down over edge of sheet (A). Finally, **(6)** Turn

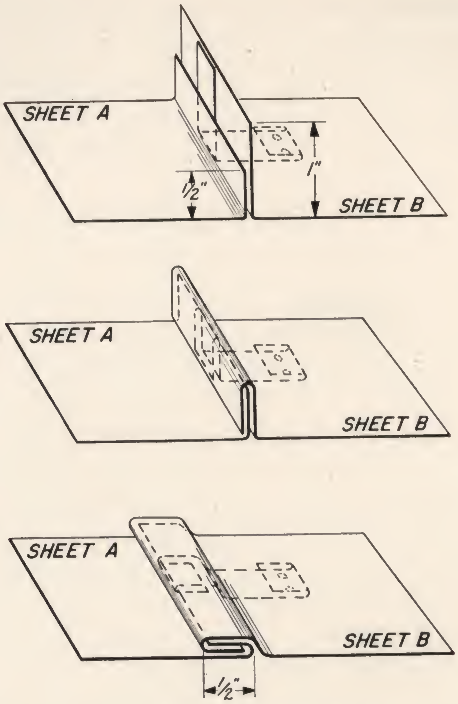


FIG. 7—DEVELOPMENT OF A FLAT-LOCK SEAM

both together 90° in same direction down on sheet (A), flatten and solder. When seam is to be cleated down, an additional step is required between **(3)** and **(4)** above;

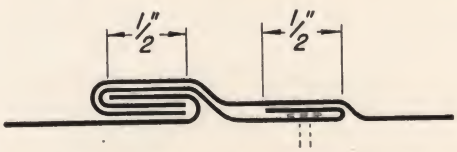


FIG. 8—FLAT-LOCK SEAM AND CLEAT

namely **(3a)**. Place cleat against sheet (A) and nail cleat to roof, turning end back over nails. Cleat then is folded in with sheets. **Fig. 8** shows a flat-lock seam with cleat.

Flat-lock seams should be at least ½ inch wide on copper up to 20-oz., and at least ¾ inch wide on heavier weights.

The remarks on page 18 about the continuous loading of seams, and the method of computing the width of lap seams on page 17, apply also to flat-lock seams, except that the maximum safe load may be taken as 375 p.s.i. of seam. As appears in **Fig. 4,** which gives the results of continuous-load tests on both lap and flat-lock seams, loads of 390 p.s.i. were sustained by the latter for 212 days, the duration of the tests.

It must be borne in mind that a soldered flat-lock seam will not withstand any tensile stress unless it is pretinned so that all surfaces in the seam will adhere perfectly. (See **Fig. 1** on page 16.)

THE STANDING SEAM

The standing seam is widely used to form the longitudinal seam between the long dimensions of copper sheets laid with the slope on roofs. It gives an attractive and interesting ribbed appearance and being unsoldered, permits expansion and contraction. This seam, too, sometimes is used as an expansion joint at the high point of a deck or flat roof.

The standing seam is actually a standing double-lock seam. It is developed as follows (see **Fig. 9**): **(1)** Bend edges of sheets at right angles, 1¼ inches on one edge and 1½ inches on other edge; **(2)** place two sheets together on roof with 1¼-inch face of one against 1½-inch face of other; **(3)** Turn projecting ¼ inch of 1½-inch face completely back 180° on 1¼-inch face of other; **(4)** Turn two sheets thus joined again 90°; **(5)** Turn again 90°; **(6)** And press folds tightly together. The seam thus formed finishes about ⅞″ high. To insure full 1″, bends are made 1½″ and 1¾″.

A ¾-inch finished standing seam is made by turning the edges 1 and 1¼ inches.

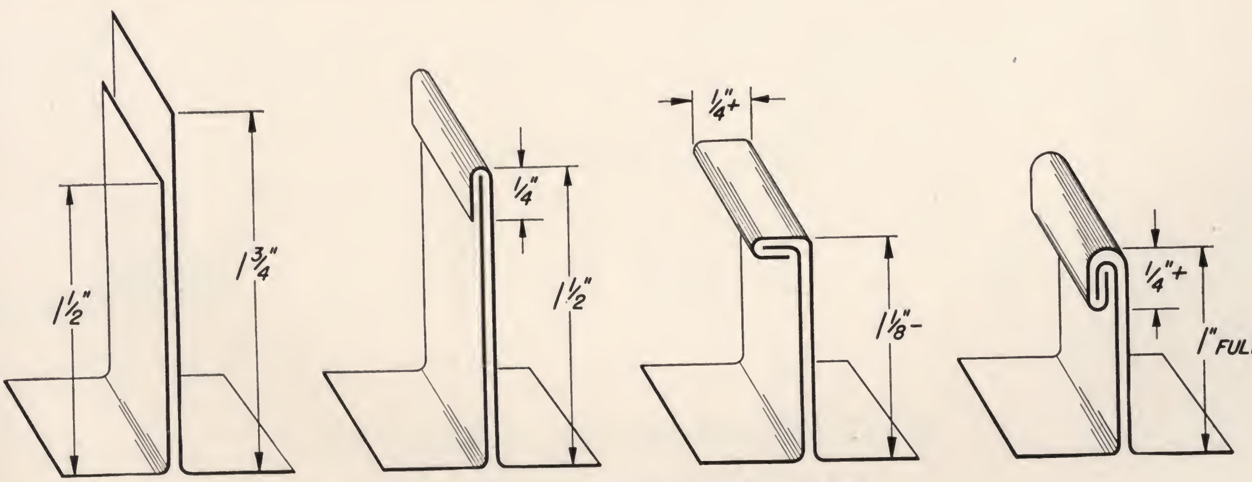


FIG. 9—DEVELOPMENT OF A STANDING SEAM

LOOSE-LOCK SEAMS

It is frequently necessary to provide for movement at places where ordinary methods cannot be used. This is particularly so where two roof planes intersect to form a ridge. Similar conditions pertain where roofing sheets join with those forming valleys and built-in gutter linings, and where standing or batten seam roofing is laid on slopes of less than 6 inches to the foot.

Movement at such points is taken care of by different kinds of loose-locks, which are variations of the simple, unsoldered hook seam. Some of these are described on page 22, and illustrated in **Fig. 16.** As can be readily seen, they are designed to act as expansion joints.

Being open they must be placed and folded so water cannot enter them. In the case of built-in gutters this means locating them higher than the outside edge of the gutter, or above the scupper level if behind a parapet wall. In the case of intersecting roof planes, the loose lock is placed close to the line of intersection and folded with the flow.

THE DOUBLE-LOCK SEAM

The double or copper-lock seam, shown in **Fig. 10,** which is virtually a standing seam bent flat, is used to avoid soldering or to allow for expansion and contraction. Two methods of making this seam are shown in **Fig. 11.** The first **(Fig. 11-A)** is often used in the shop where the sheets can be slipped together from the side after each has been folded, as shown in Detail 3.

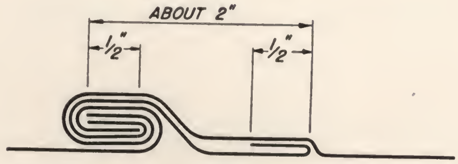


Fig. 10—Double-Lock Seam with Cleat

If the seam is located so that the sheets cannot be slid together, it is made as follows **(Fig. 11-B): (1)** Bend edges of sheet at right angles, one edge 1 inch, other 1½ inches; **(2)** Place sheets together, a 1-inch edge against a 1½-inch edge; **(3)** Turn 1½-inch edge 180° down on 1-inch edge; **(4)** Turn both together again, in same direction, another 180°; and finally, **(5)** Turn both in same direction 90° down on roof sheet, and mallet together.

The double-lock seam uses more copper by 66-2/3% than does the single lock, 2½ sq. inches being needed instead of 1½ sq. inches per lineal inch of seam.

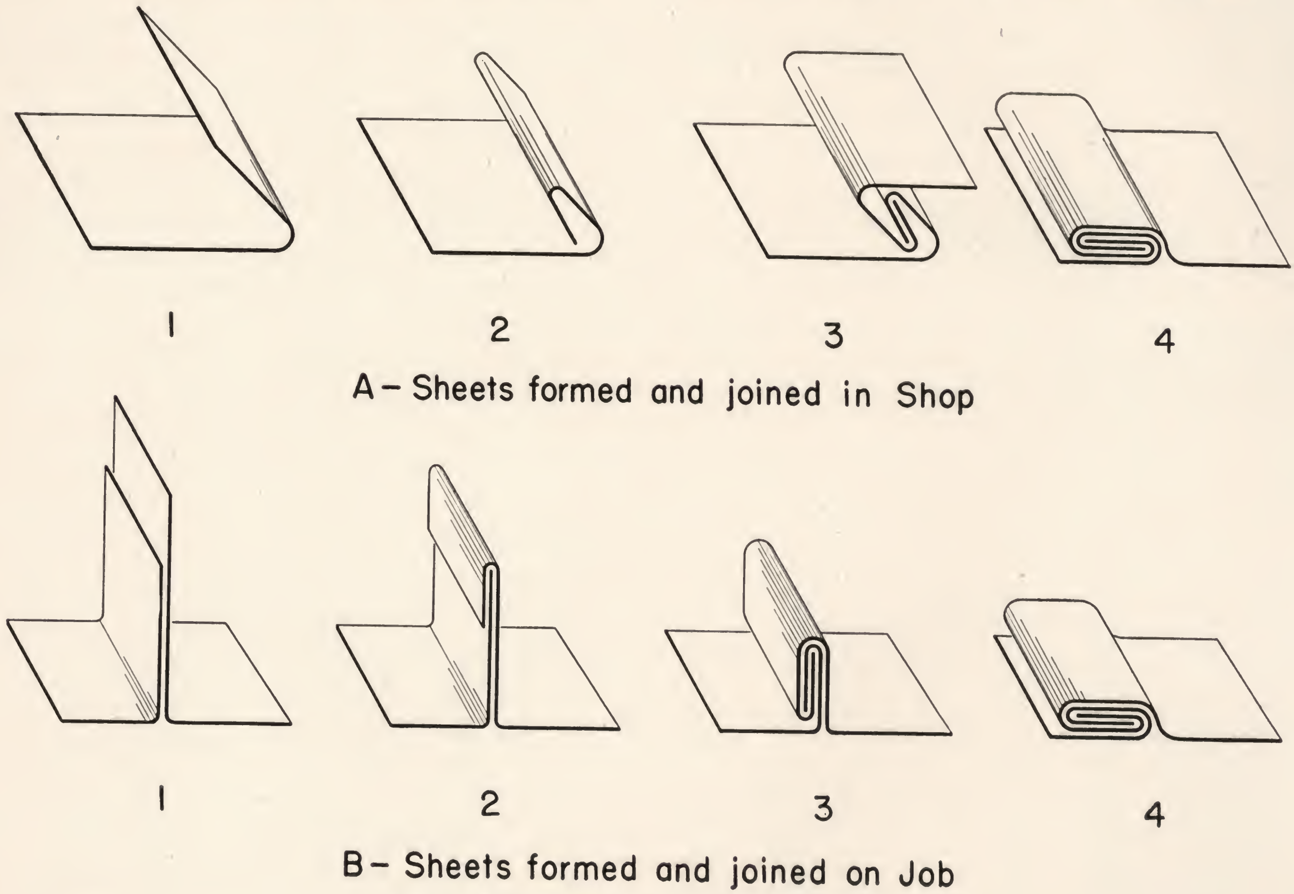


Fig. 11—Development of a Double-Lock Seam

To prevent water entering under the unsoldered edge, freezing, and opening the seam, double-lock seams should be folded with the slope, and on flat surfaces tipped with solder on the outer edge.

BATTEN OR RIBBED SEAMS

The ribbed, or batten, seam is widely used for sheet-copper roofing, and is highly satisfactory as it allows ample provision for expansion and contraction. This type of seam is discussed further under "Batten Seam Roofing", beginning on page 33. The copper sheets are formed against and between ribs, or battens, running down the roof slope. Various designs are possible for the battens, which ordinarily are of wood but may be of metal. The methods of forming the seams will vary according to the design adopted. Several types of wood batten, all of which have seen use on monumental buildings, are shown in **Fig. 12.**

The primary purpose of batten construction is, of course, to break up the long run of a roof into a number of smaller areas, so that the space required for movement of the metal at any one point will be small. Any design that accomplishes this purpose is acceptable, provided it makes allowance for both longitudinal and lateral movements of the sheets. Thus we do not recommend Types D, E and F, because: (1) they do not allow any lateral expansion of the roof sheets; (2) they do not permit longitudinal movement.

We prefer Types A and C that use separate batten covers and loose locks to facilitate longitudinal movement; and, being narrower at the bottom than the top, allow the roof sheets to increase in width without buckling.

SEAMS IN CAP AND BASE FLASHINGS

Cap flashings are usually made from 8-foot strips, a standard length for copper sheets. Good practice permits adjoining sheets to be lapped about three inches or to be joined by a hook seam **(Fig. 5).** In either case solder is usually omitted.

In base flashings, on the other hand, the seams are of the flat-lock type illustrated in **Fig. 6.** They will be about eight feet apart and should be spaced so that they do not occur with the seams of the cap flashing. They are made as is usual in flat-seam construction and are folded in the direction of the flow. The ends of the sheets are tinned and the lock sweated full of solder. The sheets being vertical, special care must be taken in the soldering to fill the seams.

On free-draining slopes greater than 1 on 4 unsoldered lap seams are commonly used with continuous base flashings.

MISCELLANEOUS SEAMS AND JOINTS

Combinations of batten and standing seam principles are illustrated in the seams in **Fig. 13.** Their construction is self-evident. They have no wide use in roofing or flashing, but have a place occasionally as expansion joints, or for ornamental purposes.

Free movement is essential at all times. Such movement is restricted when sheets pass over angles as sharp as 90°. Accordingly, where sheets must be carried over such an

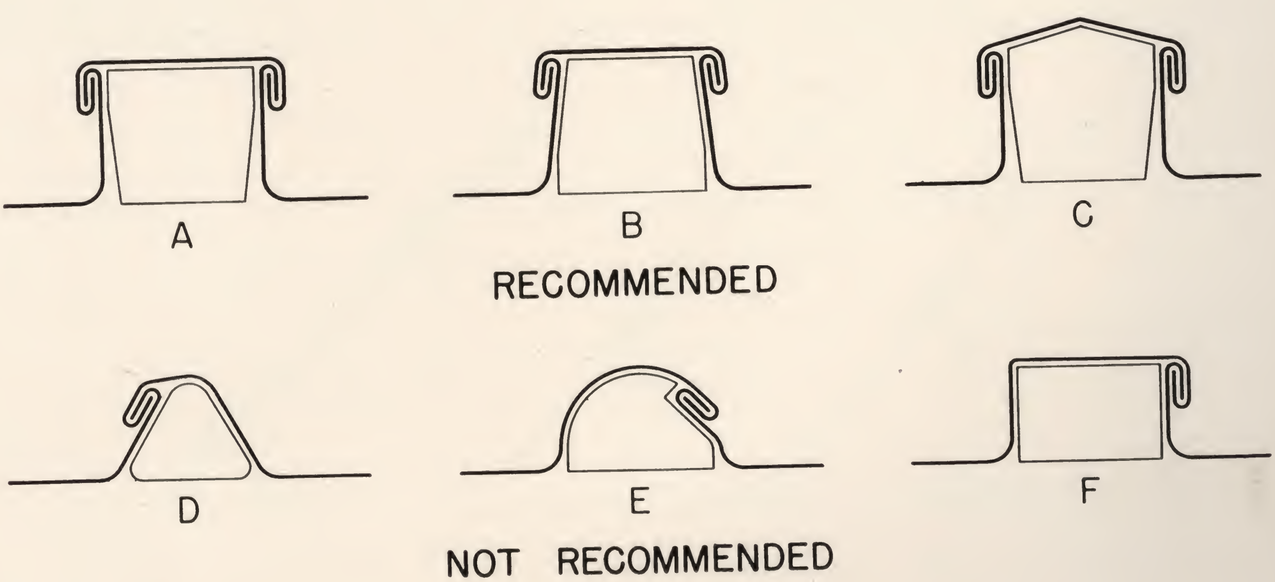


Fig. 12—Wood Battens

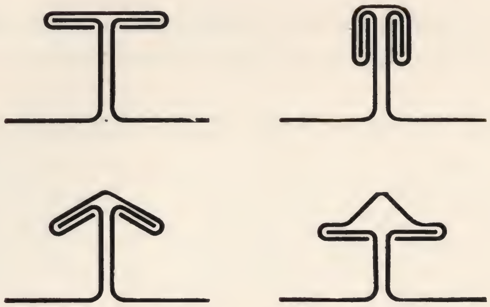


FIG. 13—MISCELLANEOUS SEAMS

angle for more than a few inches, locks should be inserted at the angles as suggested in **Fig. 14.** The double seam at the right is more secure and forms a drip edge, and is therefore, more generally used.

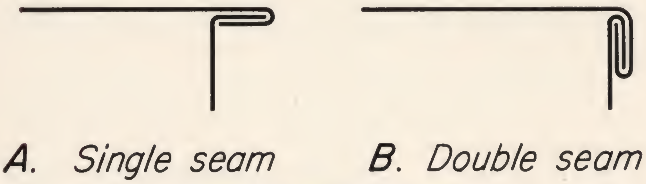


FIG. 14—CORNER LOCKS

Edge stiffeners are shown in **Fig. 15.** This practice of folding all exposed or loose edges of flashings back on themselves ½ inch is strongly recommended, as it stiffens the edge and prevents lifting by the wind and clogging with snow and ice. It also makes a neat finish. The edges are flattened together after the 180° fold.

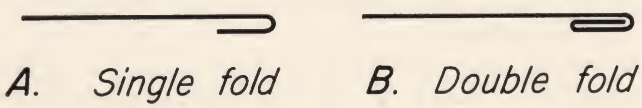


FIG. 15—HEM EDGES, OR EDGE STIFFENERS

In **Fig. 16** are shown varieties of loose-lock seams for use as joints on roof slopes and valley connections. **Fig. 16-A** is merely the flat-lock seam already described. **Fig. 16-B** shows a variation of this seam where the bottom hook is wider. This gives additional head lap (i.e., vertical distance between the lowest point of the top sheet and the highest point of the bottom sheet), and also reduces the danger of leakage from capillary action should the loose lock fill with water.

The construction in **Fig. 16-C** carries this principle further, to any desired degree. Here the upper sheet is locked into an auxilliary strip previously soldered across the entire width of the lower sheet. Any desired head lap can be obtained by varying the location of this strip. The upper edge of the bottom sheet is turned back as a hook for cleating. In the other two methods the cleats are locked into the seam.

The use of white lead to make such seams watertight is discussed on page 24, under "White-Leaded Seams."

BENDS IN COPPER

Copper sheets should be creased, worked, or bent as little as possible before laying. Every unnecessary bend that has to be flattened out later is a potential source of trouble, for the ductile metal, overstressed in bending, is weakened by flattening. At such points buckles and splits occur, sometimes years after the job is finished and accepted. It also is important in forming seams to avoid cuts, breaks and cracks at the fold. While completed seams should be malleted smooth and even, hammering should be avoided.

At all changes of direction or of planes of roofs, as where a dormer roof meets the main roof, or the bottom of a built-in gutter turns up to meet the sides, special precaution must be taken to avoid breaks and cracks.

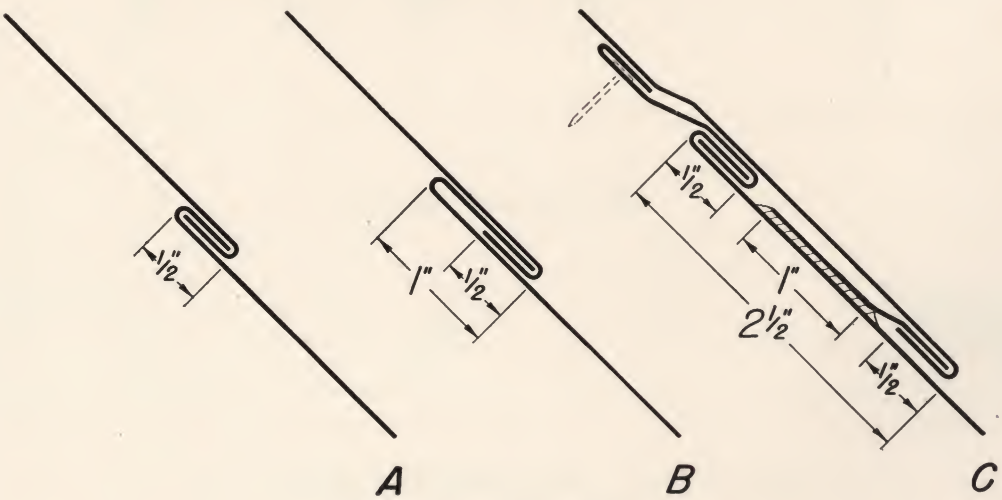


FIG. 16—LOOSE-LOCK SEAMS

Where sheets are confined in sharp angles there is a restraint of free movement and the copper warps and buckles. The sheet loses its ductility and fracture occurs, for the free flow of the sheet is prevented and a place is provided for a buckle to form.

One way of obviating this is by using small triangular blocks in corners and working the sheet over them in a gradual or easement curve.

NOTCHING SHEETS FOR FOLDING

It often is necessary to form a lock seam between sheets which pass over 90° or sharper angles. Under such conditions the metal crimps together if the sheets are folded over the corner before the seam is completed. Wherever possible the sheets should be locked together first. If this is impossible, the copper may have to be cut at the angle to permit completing the lock. Such cuts should not be slits or notches, but should be in the form of semicircles extending only half-way to the fold. Deep notches may start fractures.

EXPANSION JOINTS

The problem of expansion and contraction really is one of comparative, or relative movement, since all materials do not increase or decrease in length by the same amount for the same change in temperature. Copper has a higher coefficient of expansion than most building materials and hence tends to move more than the main structure, or the parts to which it is attached. If sufficient allowance is not made in the design, the metal necessarily will have to buckle or tear. The temperature when the copper is laid will determine whether provision must be made for expansion or contraction, or both.

Movement due to temperature changes is usually taken care of in sheet-metal roofing and flashing work by the nature of the installation itself, as for instance, standing and batten seam roofing, cap and base flashings, the use of small sheets for flat roofs, etc. Additional expansion and contraction details are described in the later discussion of installation features.

Long steel-framed structures are built with expansion joints to allow for movement in the frame. Where copper-lined gutters, or cornices, etc., are used with this type of structure it is necessary to provide expansion joints wherever they occur in the building. A commonly-used type of these is shown in **Fig. 17.** The sheets are turned up at right angles to, and slightly higher than the depth of, the gutter, the ends bent 90° to the vertical, and a cap of heavy metal locked over the top. The joint allows a small space between the vertical sides when the metal is fully expanded, and the flange length and width of cap are calculated to care for the full contraction of the metal.

This type of joint is also placed between the outlets of, and at the ends of, large built-in gutters. The top of the joint should be higher than the outside edge of the gutter so water cannot enter under the loose cap in case of outlet stoppage.

Too often in the past the design of gutter-linings has been such that they had to be locked to the roof covering and cornice strip with watertight joints. The force of expansion and contraction was insufficient to overcome the frictional resistance of such locks, so that the cumulative movement did not extend to the expansion joint. At various points where movement was obstructed critical buckles occurred that, in time, developed into splits in the sheet. To insure against such failures all built-in gutter linings must follow the principles of design and construction set out on pages 86 and 87 and shown in **Plates XXIV, XXV** and **XXVI.**

Expansion joints necessary to provide for longitudinal movement in large structures are kept moisture-proof by

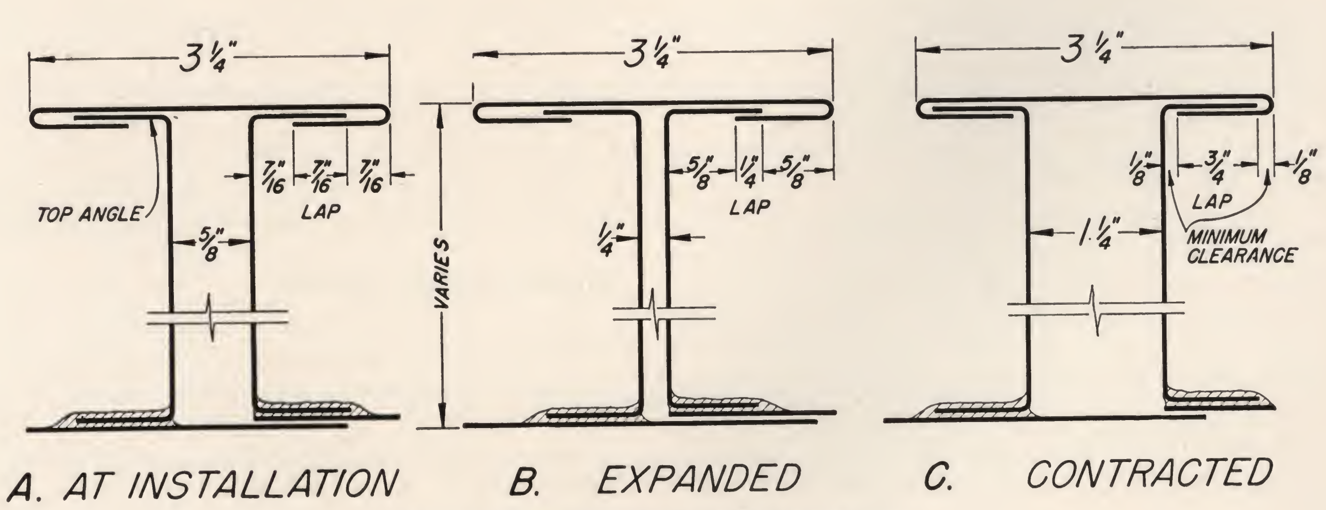


Fig. 17—Cross Sections of an Expansion Joint

a more elaborate (but similar) system of flanges and caps on roofs, parapets and walls, as illustrated in **Plate XXII.**

Expansion is, of course, a function of linear dimension only, the weight or gage of the metal playing no part. The procedure in calculating the allowance for movement in an expansion joint is shown in the following example, which assumes a 50-foot gutter, with an expansion joint midway between fixed ends, as in **Fig. 18,** laid in 90° weather in a locality having temperature extremes of 20° F. below and 100° F. above.

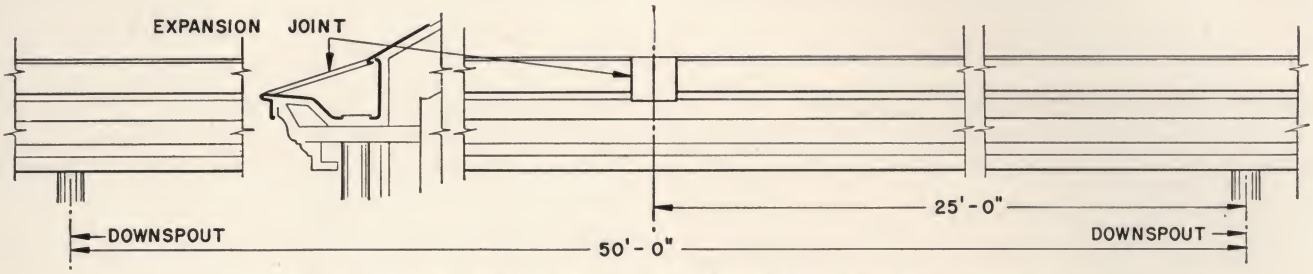


FIG. 18—GUTTER WITH EXPANSION JOINT MIDWAY BETWEEN DOWNSPOUTS

Data: Coefficient of linear expansion is 0.0000098 per degree F.
(To simplify computation this is taken as 0.00001.)
Minimum design temperature is $-20°$ F.
Maximum design temperature is $100 + 50$ superheat (see page 15), or 150° F.
Contraction temperature difference is $90 — (— 20) = 110°$
Expansion temperature difference is $150 — 90 = 60°$

Calculation: Amount of Contraction, C_n, is $50' \times 0.00001 \times 110° = 0.055$ ft. $= 0.66$ ins., say $5/8''$.
Amount of Expansion, E_x, is $50' \times 0.00001 \times 60° = 0.030$ ft. $= 0.36$ ins., say $3/8''$.
So, allowing $1/4''$ clearance with heads expanded, ClE, as in **Fig. 17-B,** the required clearance of heads at installation, ClI, is $1/4'' + 3/8'' = 5/8''$, as in **Fig. 17-A,** and the required clearance of heads when contracted, Clc, is $5/8'' + 5/8'' = 1\,1/4''$, as in **Fig. 17C.**
Total relative movement of heads is $5/8'' + 3/8'' = 1$ inch, and actual movement of each head is $1/2$ inch.
Allowing $1/4''$ laps of cap and top angles when expanded, and $1/8''$ clearances when contracted, we find that:
Length, L, of top angles is $1/4'' + 1/8'' + \frac{C_n + E_x}{2} = 7/8''$:
Total Width of Cap, K, is $2\,(C_n + L + 1/8'') = 3\,1/4''$; or
$1/4'' + 4 \times 1/8''$ (Clearance) $+ 1''$ (Total Movement) $+ 1\,1/2''$ (2 Laps) $= 3\,1/4''$; or
$1/8'' + 1/8''$ (2 Clearances) $+ 1\,3/4''$ (2 Angle Legs L) $+ 1\,1/4''$ (Head Clearance Contracted, Clc) $= 3\,1/4''$:
Fold-back of Cap is $\frac{K — Clc}{2} — 1/8'' = 7/8''$.

BUILT-IN GUTTERS

Built-in gutters are lined with copper by using rectangular sheets continuously joined by $3/4''$ flat-locked soldered seams, without cleats. The lining is installed as a "floating" unit, and is free to move at all points, except where it is fastened to the outlet, which is, of course, in fixed position. The design, to be successful, must allow for a loose-lock (unsoldered) seam at the bottom of the roof slope, and a similar loose, but watertight, lock to a strip fastened at the outer edge of the cornice to the supporting structure.

Details of construction are described and illustrated on pages 86 to 93 and in **Plates XXIV, XXV,** and **XXVI.**

WHITE-LEADED SEAMS

The use of white lead to caulk folded seams in copper is not new. In fact it seems to be somewhat of a lost art, as it was accepted practice in this country in 1831, when the dome of the State House in Boston was sheathed with white-leaded, flat-seam copper roofing, and for 70 years thereafter. Many monumental buildings of the late '90s were covered with copper laid with white-leaded seams.

However, with the turn of the century rising costs seem to have favored cheaper methods, such as the loose locks used with standing seam and batten seam roofing on steep slopes. White-lead paste was not commercially available. It had to be hand-mixed in the shop, a tedious, costly and disagreeable job. With the introduction of improved solders and fluxes, soldering could be done faster (and cheaper) than, and as satisfactorily as, caulking.

Today, of course, white-leaded seams can compete in cost with soldered ones.

Their use is recommended under conditions calling for tight joints and movement, for the lead paste allows a certain freedom or elasticity not possible with solder. Actual tests (see foot note, page 16) have shown that flat-lock seams caulked with white lead will not leak under water up to four inches deep. Such seams are cheaper than are soldered seams, and the use of white lead obviates the conspicuousness of the soldered joint. White-leaded seams can be used where: (1) soldered seams will be unsightly, as on a spire or dome, and there is danger of wind forcing water behind loose-locked seams; (2) copper is to be covered with gold leaf that will not adhere where any flux remains; (3) copper must be free to move and still keep out water flowing over it; (4) water cannot back up and form a head of more than 4″, as in gutters equipped with scuppers, or on areas covered with flat-seam roofing laid in panels, as illustrated in **Plates VII** and **VIII**.

The recommended white lead paste is composed of 92% (by volume) basic lead carbonate and 8% boiled linseed oil. It must be smooth and of putty-like consistency. The paste is smeared generously onto the edges of the sheets and is folded directly into the lock as the seam is formed. All excess lead should be removed.

FASTENINGS FOR COPPER WORK

As the right kinds of fastenings are essential to the proper installation of sheet-copper work, these definite rules should be followed:

I. All fastenings should be of copper or a copper alloy;

II. Never secure sheets in any way that will prevent some free movement;

III. All pieces of copper forming parts of roofs, or other large units, should be cleated;

IV. Fasten copper flashings more than 12 inches wide with cleats.

Rule I merely is an application of the principle that dissimilar metals must never be in contact. (See page 13.) This applies not only to nails but to hangers, brackets, braces, and to screws and rivets.

Rules II, III, and IV are corollary to the fundamental rule that provision must be made for expansion and contraction. Cleats permit such movement, and also restrict it to each sheet so the movement is not multiplied throughout the entire copper work.

Strips less than 12 inches wide, as flashings, edge strips, etc., may be secured by nails. In such instances the nailing should be restricted to one edge. Nails should be near the edge and evenly spaced, not more than 4 inches apart.

A common source of flashing trouble derives from failure to observe Rules II and IV in valley flashings. These, by their very nature, usually are from 16 to 24 inches wide, and must be secured on both sides. **Fig. 19** shows a valley flashing. If such a flashing is nailed, two things may result from movement through extreme temperature ranges: the flashing may tear at the nails and become loose, or the sheet may buckle along the edge of the roofing material. With the first, water works under the loose flashing; with the second, splitting or cracking occurs from fatigue of the metal.

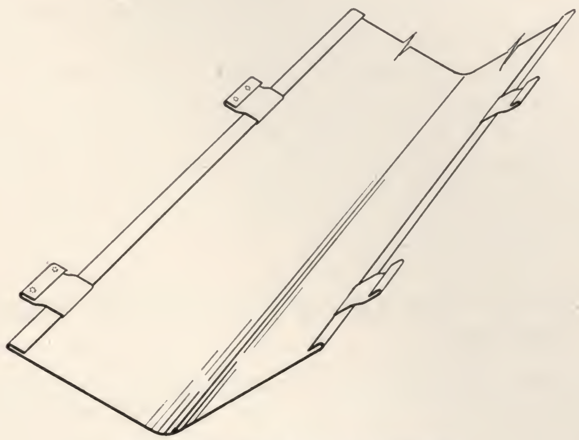


FIG. 19—OPEN VALLEY FLASHING

CLEATS FOR COPPER WORK

Cleats should be made of 16-oz. cold-rolled copper, not less than 2 inches wide, and should be fastened with two copper or copper-alloy nails as shown in **Fig. 20**. A width of 2 inches is preferable, as it gives a stronger cleat and minimizes the possibility of the nails tearing out.

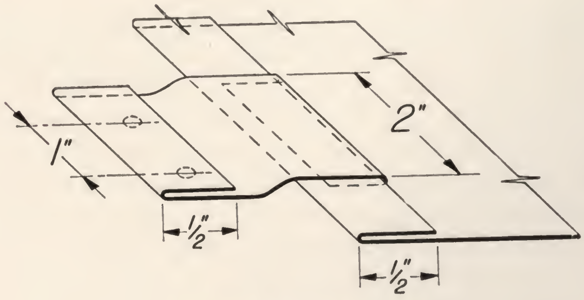


FIG. 20—A COPPER CLEAT

The nails are placed parallel to the edge to prevent turning. The end of the cleat is bent back over the nails to prevent the nail heads from cutting the sheet.

The length is determined by the kind of seam with which it is used.

Maximum spacing should not exceed 12 inches; a spacing of 6 or 8 inches is recommended. This does not apply to concealed valley flashings, etc., where the sheet or strip is held by the roof covering. Under these conditions the spacing may be increased considerably; a maximum of 24 inches is recommended.

The cleat holds the sheet as shown in **Fig. 20.** If it also secures a second sheet, it is folded in with the sheets as the seam is formed. In such cases the cleat must be nailed down before the sheets are brought together.

Under special conditions, as where seams must be fixed in place so as to force thermal movement away from them toward an expansion joint, cleats should be heavier than 16-oz. Actual thickness can be determined by calculating the stresses, as on page 17.

COPPER AND COPPER-ALLOY NAILS AND SCREWS

Many flashings, such as gravel stops, those around window and door openings, and some eave strips, must be nailed. In these cases the four rules for fastening on page 25 are still observed, for the copper strip is fastened along one edge only and is free to move in a direction normal to the line of nailing. The longitudinal movement is taken care of by placing the nails a short distance (4 inches is the recommended maximum spacing) apart. As the total movement, through a temperature of 170° F., between nails spaced even as much as 12 inches will be less than 1/50th of an inch, there is little danger of tearing or splitting because of strain.

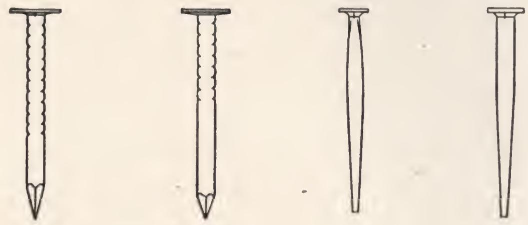
The cost of nailing with nails spaced 4 inches is not enough to justify risking failure of flashings at such vulnerable places as wall openings and roof edges.

The folly of using iron or steel nails with sheet copper, already discussed under "Dissimilar Metals—Electrolysis" on page 13, cannot be over-emphasized. No economy results from saving a few dollars in nails that quickly corrode and thereby bring about failure.

The proper nails to use with sheet copper are large flat-head wire nails, not less than 12 ga., with barbed shanks and diamond heads, as illustrated in **Fig. 21-A.** These are known as "Copper Wire Slating Nails", and differ from ordinary wire nails in the design of the head, and the shank immediately under the head, the barbs on which act like diminutive fish hooks in the wood fibers. As can be seen in **Fig. 21-B,** the ordinary wire nail has a ridge or shoulder under a smaller head. This makes it impossible to drive the nail home without tearing the sheet around the clean hole formed by the shaft. Moreover the smaller head does not have enough gripping surface to hold well.

Figures 21-C and **21-D** show cut nails regularly used for shingles and tile roofing. These nails have a greater holding power (2 or 3 times) than wire nails of the same length, but their disadvantages for use in sheet copper work are obvious. The shank tears the sheet and the head, if driven home, punches through. For ordinary use in wood sheathing, the holding power of the large flat-head wire slating nail is satisfactory.

In exposed locations, or wherever a special holding power is required, heavy (10 ga.) wire nails with barbs the full length of the shank are recommended. Cement-coated nails, and etched nails, also develop tremendous gripping power in wood.



A. Copper Wire Slating Nail
B. Copper Wire Nail (Similar to Steel Wire Nails)
C. Regular Cut Copper Nail
D. Large Flat-Head Cut Copper Roofing Nail

Fig. 21—Copper Nails

There follows a list of Copper Wire Slating Nails promulgated July 1, 1934 by the U. S. Department of Commerce, with the approval of the industry and its customers, through the National Bureau of Standards, under Simplified Practice Recommendation R150-34:

Length (In.)	*Stubs' Gage*	*Decimal Equivalent (In.)*	*Approx. Number To The Pound*
1	12	0.109	292
1-¼	12	0.109	240
1-¼	11	0.120	208
1-¼	10	0.134	164
1-½	12	0.109	204
1-½	11	0.120	164
1-½	10	0.134	132
1-¾	10	0.134	116
2	10	0.134	108

Cut slating or roofing nails of brass and Naval brass are standard for slate and tile roofs, where large nails, 2″ or longer, of considerable holding power are required. The length of the nail necessary to give sufficient penetration into the nailing base which often is gypsum or nailing concrete, demands an alloy harder than copper.

Cut slating and roofing nails of brass and other copper-

alloys are also used to attach slate and composition shingles to roof. They are like ordinary cut copper nails, except that, to get more holding power, they are made from heavier gage material and with larger heads.

Copper and copper-alloy tacks are in general use for fastening canvas decks, screen cloth, etc., or wherever a tack is needed that cannot rust.

SCREWS AND PLUGS

Brass and other copper-alloy (all preferably hard) screws are often used to fasten sheet copper. This is generally the practice where the sheets must be secured to masonry **(Fig. 79, Plate XVIII)**, and is always so where the pieces—such as ridge-rolls—are exposed to the continuing vibration of severe winds **(Fig. 51, PlateX)**. Nails driven into lead plugs set in the masonry are commonly used for base flashings **(Fig. 74, Plate XVII)**, or where there is other protection against strong wind action.

Screws should be round-head because this kind has a flat undersurface that does not tear the thin sheet, as happens when flathead screws with their countersunk sides are tightened into place on yielding surfaces. Flat-head screws can be used in brass edge-strips with countersunk holes **(Fig. 30, Plate III)**, because the bearing surface of the strip keeps the thin sheet firmly in place as the screw tightens and prevents ripping.

It is standard practice (although not always shown on the Plates) to place a lead washer between screw and sheet, as thus the screw can be set without tearing the sheet around the hole, and the lead will squeeze into the space between screw and sheet and make it watertight.

When it is not expedient to cut or form reglets in masonry, holes are drilled along the line of fastening. These holes are filled with expansion sleeves, either patented or made from thin pieces of sheet lead rolled tight, and into them brass screws are driven **(Fig. 79, Plate XVIII)**.

In England sheet copper is used instead of sheet lead (see page 68).

Screw holes should always be slightly larger than the screw so as to spread the strain when a screw is driven eccentrically. Where water or dampness must be kept out small copper cups are soldered over the screwheads **(Fig. 50, Plate X)**.

SURFACES FOR LAYING COPPER

Before applying copper to any surface it should be smooth and even, and free from all small projections and hollows. Surfaces should be absolutely dry when copper is laid. In re-roofing work, over wood sheathing, the wood must be in good condition, or must be replaced before the copper is laid.

WOOD SHEATHING

Wood sheathing forms an excellent laying surface for sheet copper. It should be of well-seasoned, straight, unwarped boards, free from splits and knot holes. It should be firmly nailed down, with all joints true and even and all nail heads set. Sheathing, after being laid, should weather a number of days while protected against rain; and no copper should be laid unless the boards are thoroughly dry.

Sheathing boards should be ship-lap, tongued-and-grooved, or splined. Ship-lap, perhaps, is the most satisfactory as it is easier to lay and offers less trouble from warping and swelling.

The ideal sheathing is kiln-dried lumber, impregnated to withstand decay. It should be used on all jobs where protection of the interior is an important factor, and on buildings of such size that the roof is a comparatively small part of the total cost. As it is expensive, on less important work satisfactory results can be had with air-dried boards. Green lumber *never* should be used.

CONCRETE AS A BASE

When copper is laid on concrete the surface should be made smooth by a wash of neat cement. Heavy coats of asphalt paint also are satisfactory for this purpose, provided asphalt and copper are separated by a layer of rosin-sized or similar building paper.

Cinder concrete should not be allowed to come in contact with copper because cinders have ingredients that combine with moisture to form injurious solutions. Where copper is to be used over this material the concrete should be covered with a heavy coating of asphalt paint.

Some provision must be made for receiving the nails to fasten cleats. Wood battens or expansion inserts can be set into the concrete. Various nailing concretes are available. If the material to receive the nails does not extend over the entire area, it must be placed where the seams, and hence the cleats, will fall.

GYPSUM AND MISCELLANEOUS LAYING SURFACES

Gypsum, Porete, and similar roof-sheathing materials also are well adapted for use as a base for copper roofing. What has been said of concrete also will apply to such materials, except that most of them can be nailed into directly. It is important, however, that the proper nails be specified to give necessary holding power. A 2-inch nail penetration into gypsum is required; and as this demands

nails of greater stiffness than pure copper, copper-alloy nails are indicated.

Other laying surfaces, such as terra cotta, stone, brick, or stucco often are encountered in flashing work. These should be treated with neat cement or asphalt, as is concrete, to provide a smooth surface free from sharp corners or projections.

BUILDING PAPER OR FELT

Under all copper roofing, valleys and gutter linings there should be used a layer of roofing felt covered by a layer of smooth building paper (such as rosin-sized) to provide a smooth, unimpeded laying surface and to minimize the formation of moisture from condensation on the under side of the copper. Over abrasive surfaces like concrete (except cinder concrete as on page 27) felt is a necessary protection.

To serve these purposes the paper must be tough and durable. Asphalt roofing felt is admirable, and for fireproof construction the National Board of Fire Underwriters recommends asbestos-felt paper about 1/16th of an inch thick, weighing about 14 lbs. per 100 sq. ft. or 70 lbs. per standard roll of 500 sq. ft.

Field observations and laboratory tests have shown that the asphalt-saturated felt commonly used under copper bleeds under the summer heat. The soft pitch thus released forms a bond between copper and supporting surface that hinders free movement. For this reason a smooth non-asphalt building paper should be laid over the roofing felt. If the latter is properly nailed (copper nails spaced 3 inches on lapped seams) the paper need be nailed only every 18 inches.

When copper is used as a flashing at a junction with other roofing materials such as slates, shingles, tiles, etc., the felt or building paper under the roof covering must be lapped properly with respect to the copper. When the drainage is from the roofing onto the copper, the felt, or paper under the shingles should lap over the copper and its underlying paper.

TREATMENT OF COPPER WORK

MAINTENANCE

Copper work requires little or no maintenance if properly installed. No painting is necessary, and its attractive green patina, which forms in time, is a protection. Periodic inspection should be made as a matter of routine to see that no physical damage has been done, to be sure all outlets are unclogged, and to remove all foreign matter that may have been deposited on the roof.

CLEANING

All copper work when finished should be cleaned of flux, scraps and dirt. On large roofing jobs this should be done as soon as the various sections are finished. Foreign matter, besides being unsightly, may cause permanent discoloration and other serious damage. Excess flux, which may cause acid stains, can be neutralized by washing with a 5% to 10% solution of washing soda.

For painting and artificial coloring of copper, a clean surface is essential. A slightly tarnished surface is favorable to best results. Copper weathered by two or three rainstorms is in the best condition for painting and artificial treatment.

PAINTING

When desired, copper may be given a satisfactory and adhesive coating of paint to obtain any desired color effect. Copper to be painted must be free from dirt and oil or grease, and absolutely dry. Copper that has weathered through two or three rainstorms will ordinarily have had the oil film, remaining from rolling operations, washed from the surface. This is best indicated by the appearance on the copper of a slight tarnish resulting from its oxidation by the atmosphere. This is the best condition of a copper surface to obtain a satisfactory spread and adherence of paint. In fact, the more the copper is weathered, the better its condition for painting.

COLORING

Copper may be given an artificial green patina. The best process available at the present time is that described in Booklet No. 15-B "Coloring Copper, Brass and Bronze," as issued by this Association. The process described has been used successfully, but it is dependent to a considerable extent upon weather conditions at the time of application of the treatment. There is no known process which can be guaranteed to give an exact duplication of the patina of basic copper sulphate that forms in time by natural weathering.

COLORING SEAMS

Sometimes it is desirable to make seams inconspicuous by coloring the solder to match the copper. This can be done by dissolving sulphate crystals (blue vitriol) in water and making several applications with an iron rod or brush. Soldered seams also can be concealed by touching up with copper bronze.

LEAD-COATED COPPER

Lead-coated copper is what its name implies—copper coated with lead on both (or one) sides of the sheet.

It is a strong but ductile and workable metal that extends the architect's range of expression by making available to him a decorative covering with a wide variety of color tones and surface textures, from the natural soft gray of newly-cast lead to dark-weathered antiques, and from glossy, smooth surfaces to those that are rough with countless ridges and indentations.

In a sense, lead-coated copper is a recent development in the field of useful metals; and yet it has been in service sufficiently long to have proven its value in a practical as well as ornamental way. So far as it is of record, the first application in the building field was just prior to World War I. Its invention resulted from a search for a material that would give the appearance of lead at a much lower cost and with less dead weight.

SOME ADVANTAGES OF LEAD-COATED COPPER

The good points of lead-coated copper can be summarized as follows:

(1)—**Finish**—As far as weathering and durability are concerned it is equal to copper. Moreover it takes paint readily and holds it as well, if not better, than other metals.

(2)—**Stiffness** and strength are supplied by the copper, thus making it possible to use lead-coated sheets in the same manner and for the same purposes that copper is used.

(3)—**Lightweight**—Because of its lightness, as compared to sheet lead, the design dead load of roofs, domes, spandrels, ornaments, etc., can be kept low.

(4)—**Nonstaining**—Lead does not stain adjacent materials as sometimes happens with copper, especially where exposed to saline or smoke-laden atmosphere. For this reason, lead-coated copper is widely used for flashing stone, marble, stucco and concrete work.

(5)—**Ease of Forming**—Because the lead coating acts as a lubricant, stamping and embossing reliefs and ornaments are more easily done, and with even greater delicacy of detail, than in copper sheet.

SUGGESTED USES

Lead-coated copper can be used in practically any type of building wherever metal can be applied for utilitarian or ornamental purposes, such as:

Balustrades	Fleches	Roofing
Canopies	Gutters	Skylights
Cornices	Hoods	Spandrels
Crestings	Leaders	Spires
Curved Surfaces	Leader Heads	Steeples
Domes	Marquees	Towers
Dormers	Minarets	Turrets
Flashings	Ornaments	Ventilators
	Panels	

HOW TO SPECIFY SHEETS

For ordinary roofing 16-oz. copper is the accepted weight, but where special conditions obtain heavier sheets must be used. Soft or cold-rolled copper can be lead-coated, but, for reasons discussed elsewhere (page 13) cold-rolled is recommended. Lead coating is done by two different processes, electrolysis and dipping. The former produces smooth textures that are not as popular as the rough finishes obtained by dipping. As the heat from the lead, which is applied molten to the copper in the dipping process, removes some of the temper of the latter, it is good practice, whenever stiffness is a requisite—as in cornices and decorative spandrels, etc.—to increase the gage to at least 20-oz.

Lead-coated copper is commonly furnished in accordance with the American Society for Testing Materials Specification B-101, 1945, which covers different weights of sheets and coatings. The weight of coating is designated as the total pounds of lead applied to two sides of 100 sq. ft. of copper sheet. Sheet can also be coated on one side only, or with special textures and finishes, or with any desired weight, under special agreement with the manufacturer. Most of these have their own trade names for the various weights and textures.

IMPORTANCE OF GOOD COATING

Observations of many hundred installations of lead-coated copper over the past twenty-five years have focused attention on a few failures by pitting of the lead surface and corrosion of the undersheet of copper. Laboratory investigation of this phenomenon has demonstrated that it is due to inadequate coating unevenly applied over the copper surface. Porous areas showed tiny bare spots like pin holes with the copper exposed. These minute pockets retain moisture and galvanic cells form that accelerate corrosion from electrolysis.

It is very important, therefore, that the leadcoating be done by persons or firms qualified by experience and

reputation for knowing how, so that thin and porous areas, oxide inclusions and pin holes will be reduced to the commercial minimum.

Prospective users of lead-coated copper for any purpose will do well to first consult with the technical staffs of the manufacturers, to determine the best weight of copper sheet and lead coating.

METHOD OF APPLICATION

The method of applying lead-coated copper for roofing and other sheet-metal work is practically the same as for plain sheet copper. The same types of seams and solder are used as for plain copper.

However, there are certain precautions that should always be observed. As lead is a very soft metal it must be carefully handled to avoid cuts and scratches. And particular care must be exercised in soldering. Either liquid or paste fluxes of the zinc-chloride type can be used, provided great care is taken not to swab on excessive amounts, and to wash off all excess flux. In the actual soldering operation the seams must be well covered with the coating metal or with solder so that no copper is exposed. A non-acid solder should be used.

LEAD-COATED SPANDRELS, ETC.

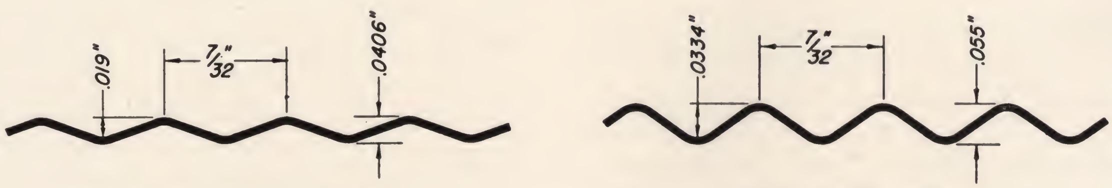
The subjects of lead-coated copper or copper-alloy spandrels, vertical trim and horizontal band courses cover such broad fields as to preclude any but general statements in this book. Made of formed or stamped sheets, they vary in size and in method of construction, as well as in the gage of metal. There also is wide latitude in methods of framing, connecting, and securing unit parts.

Because of the many variations in the design of spandrels, etc., specifications are usually written to fit the special conditions of each installation. If special problems arise in connection with this subject, assistance may be obtained from this Association.

TINNED COPPER

Copper sheets tinned over their entire surface are never used for any type of roofing, flashing or gutter work. They are subject to pitting and will fail in such service in a relatively short time.

CRIMPED COPPER



16 OZ. STANDARD CRIMP   16 OZ. HEAVY CRIMP

Fig. 22—Crimped Copper

The use of crimped copper is well established for formed shapes such as cornices, domes, cupolas, ornamental figures and urns, etc. The small crimps permit a "bellows" action for expansion and contraction not possible in plain sheets, and give a pleasing character to plane surfaces. It is well suited for vertical walls and plain and panelled areas. As shown in **Fig. 22** above, the crimps consist of 7/32-inch V-shaped corrugations running crosswise with the length of the sheet. Crimping tends to harden the copper, although not greatly.

The widest use of crimped copper probably is for cornice work, for both ornamental and practical reasons.

Crimped copper can be used for through-wall flashings but the crimps should not be expected to furnish a complete masonry bond. The corrugations are not deep enough for this purpose. The type of construction shown in **Figs. 80, 81** and **82** or the various patented flashings referred to in the section on flashings (page 76) are used.

CORRUGATED COPPER

Corrugated metal consists of flat sheets rolled into a continuing series of parallel symmetrical waves. The corrugations can vary in width and depth, but usually are in the form of circular arcs. Typical corrugations are shown

on **Plate IX**. The primary purpose of the corrugations is to add strength to the sheets. They also aid in the discharge of rain water.

Corrugated copper sheets most frequently are used in heavy gages. The wings of the United States Capitol were roofed in 1859 with corrugated copper which still is giving satisfactory service. The metal in this installation is at least 30-oz. copper, sheets 24 ins. wide being laid on purlins, spaced 24 ins. center to center, to which they are fastened by angle brackets riveted to the sheets, and secured to the upper side of the purlins by bolts. As there is no sheathing or other support under the sheet, the necessity for using heavy metal is obvious.

Tests on corrugated copper sheets under uniformly distributed loads demonstrated, as would be expected, that sheets continuous over two spans show decreased deflections and more rigidity. The amount of permanent set in the sheets under load for six weeks was found to be very small; the rate of increase of the set after this period was negligible.

The method of laying corrugated sheets is shown in **Plate IX** and discussed on page 52.

LIGHTNING PROTECTION

Complete rules and directions for installing lightning protection systems are published by the Underwriters' Laboratories. They also list a number of companies whose lightning protection systems conform to standards they have established for their "Master Labeled Lightning Protection Systems."

Copper roofing of all kinds and its accessories, such as downspouts, may act as excellent adjuncts to lightning protection systems, but are not recognized by Underwriters' Laboratories as a substitute therefor. All such copper work coming within 6 feet of lightning conductors should be interconnected with them by a conductor of not less than an equivalent of No. 6 B. & S. gage copper wire. Extensive copper roof areas that do not come within this distance of a regular lightning protection system should be independently grounded.

The Copper roof on the Cathedral at Hildesheim, Germany, was, until it was destroyed by aerial bombs in March, 1945, the oldest known Copper roof in the world. Portions of it had been untouched since it was laid, according to ancient records, in 1230 by order of Bishop Konrad (1221-1246). The gilded Copper cupola was added in 1367.

SECTION II—ROOFING

In designing the structure upon which the roof covering is to be placed the limitations of the roofing material to be used, drainage arrangements, and the type and design of the gutters must be considered. Information on drainage begins on page 113.

Roofs may be flat or made up of a combination of slopes. While this leads to a large variety of styles, the principal types, of which all others are variants, can be defined as: the gable; the hip; the gambrel; the mansard; and the flat.

Copper can be used on all types of roofs. It is, furthermore, the flashing and accessory metal universally used with better class roofing materials. The three standard methods of applying copper for roofing are as follows: (a) Batten or ribbed seam; (b) Standing seam; and (c) Flat seam.

These methods make use of flat sheets, and will be discussed in detail. Complete information can be obtained from individual manufacturers about corrugated roofing sheets and copper shingles and tiles, a variety of which can be had from stock dies that imitate closely shingles and tiles made of other materials. This Association can furnish lists of these manufacturers.

SOLDER AND WHITE LEAD

It is desirable, in copper work, to eliminate soldering wherever possible so that the sheets will be free to move. Copper roofing held with loose-lock seams and cleats is free to move, but such seams must be tight if water can back up over them or be drawn into them by capillary attraction. On steep slopes of 6 inches to the foot or more that drain rapidly, seams need not be soldered. But wherever they are exposed to the driving force of rain—or snow-bearing wind—as on mansards, gables, domes, spires and towers, the seams are filled with white lead paste (see page 24).

In batten and standing seam roofing lateral expansion and contraction can be cared for rather simply. Longitudinal movement is more difficult to handle if the cross-seams cannot be left unsoldered. In such cases the use of 4 ft. sheets, instead of the standard 8 ft. sheets is suggested. Employing smaller sheets introduces more seams which tend to stiffen the surface and minimize buckling.

For slopes with low pitches, special attention is directed to the "strip-pan" method of forming the cross seams in batten and standing seam roofing. This does away with soldering and makes the joints watertight by providing the required head lap.

In flat-seam roofing solder must be used wherever water can back up from outlet stoppage, or snow or ice can collect. The method of providing for expansion and contraction in this type of construction will be discussed under flat-seam roofing. (See page 48.)

SLOPES

The slope of a roof, determined by the style or design of the building and climatic and drainage considerations, will dictate the best method of applying sheet copper, both as to the standard method to be employed and details of its use. In general, the flat-seam method is used for flat roofs and decks, and for domes and cupolas; the standing and batten seam methods for sloping roofs. The limitations of slope in the standard types of copper roofing are as follows:

Batten seam—minimum slope 3″ per foot;
Standing seam—minimum slope 2½″ per foot;
Flat seam—minimum slope ¼″ per foot, or dead-level.

Four ways of defining the pitch, or slope, of a roof are in general use:

1. In terms of the vertical rise in inches for each foot of horizontal run, as—"one inch to the foot";
2. In terms of a fraction denoting the ratio of the total rise of the roof to its total span, as—"¼ pitch or slope"—that is, the height of the roof is equal to ¼ of its total span, assuming two equal and opposite intersecting slopes (for a single slope the fraction is obtained by dividing the vertical projection by twice the horizontal projection);
3. In terms of the angle, measured in degrees and minutes, between the roof slope and the horizontal, as—"slope of 18° 25′ ";
4. In terms of rise (vertical) to run (horizontal), as "5 on 12 slope," which means the roof rises 5 inches for each 12 inches of horizontal width, the example in (1) being "1 on 12 slope," that in (2) being "1 on 2 slope," that in (3) being "4 on 12 slope."

The curve in **Fig. 23** shows lengths of valley slopes formed by the intersection of gables having identical slopes. The use of this curve is shown by the following example:

Let the rise, H, of the roof be 9″;
and the run, W, of the roof be 12″.

$$\text{Then } \frac{H}{W} = \frac{9}{12}, \text{ or } \frac{3}{4}.$$

Find this value of $\frac{H}{W}$ on the horizontal scale at the bot-

tom of the chart, and follow the vertical line upward until it intersects the curve; thence project a horizontal line to the left to intersect the scale "S", as it does, at 15". This, then is the length of valley for each foot of horizontal run. Thus, for a run of 6'—3½", length of Valley Slope, S, is

$$\frac{15 \times 6.29}{12} = 7.86 \text{ ft., or } 7' - 10\tfrac{3}{8}''.$$

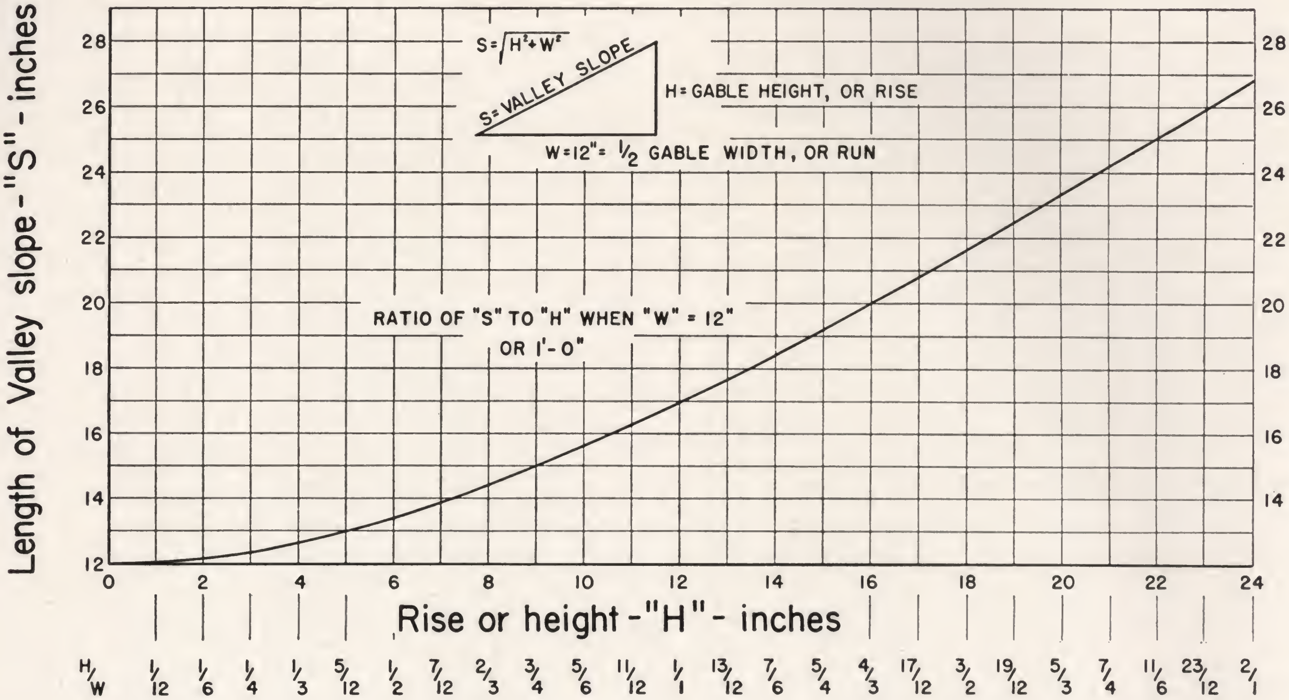


Fig. 23—Lengths of Valleys Formed by Intersections of Roof Planes with Identical Slopes

BATTEN, OR RIBBED, SEAM ROOFING

In this type of roofing the surface is broken up by evenly-spaced parallel battens, or ribs, running with the slope of the roof. The roof cover is of cold-rolled copper sheets that fit between these battens, and lock to caps or covers over them. This construction gives plenty of room for expansion and contraction, providing consideration is given, at the time of laying, to local temperature ranges.

The vertical, lifting effect of the battens makes this type of roofing an excellent cover for the large gable and mansard areas of public buildings, churches, terminals and offices, because it combines dignity with ornamentation. It can be used on slopes of 3" to the foot or more. It always should be borne in mind that, as the longitudinal seams at the battens are unsoldered and, therefore, not watertight, it is not safe to use this method on slopes as low as 1 on 4 in localties where ice and snow collect.

TYPES OF BATTENS

Battens usually are wooden strips fastened to the laying surface. A variety of shapes are possible, as shown in **Fig. 12**, but for general use the types illustrated in **Fig. 24** are recommended. They are usually cut from a square or rectangular strip with the sides bevelled so that they are symmetrical. The bottom corners are bevelled off slightly (**A or C**) so as not to restrain the lateral movement of the copper sheet.

Battens preferably are made of cypress, although spruce and pine are commonly used. They should be thoroughly seasoned, straight and sound, and impregnated to resist rot and insects. The surface must be smooth and all nail heads must be set. If the roof surface is of any material other than wood, the battens should be bolted in place, with bolt heads countersunk.

Battens of heavy copper, or copper alloy, can be used. Their design follows the principles recommended for wooden battens and their installation, including all fastenings, should be in accordance with the general rules for copper work. As such battens assure durability, stability, and accuracy of line, they are recommended for large,

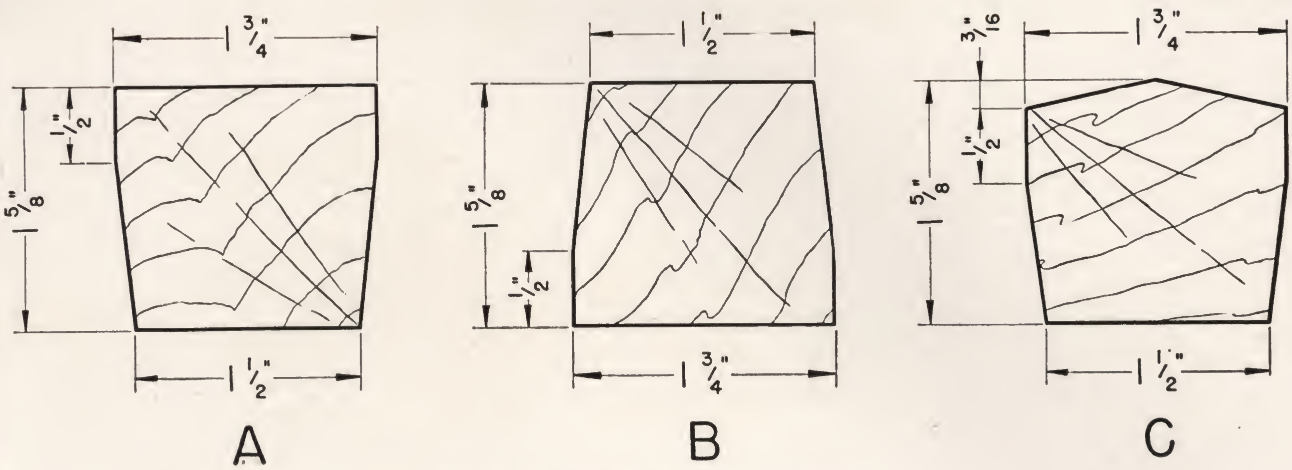


FIG. 24—DIMENSIONS OF WOOD BATTENS
(Minimum for slopes up to 1 on 2.)

important structures, where maintenance over a long period is an appreciable part of operating cost.

SIZE AND SPACING OF BATTENS

The size and approximate spacing of battens usually are determined by architectural considerations. They are ordinarily spaced from 20 to 30 inches apart, the exact spacing being adjusted to fit stock widths of copper sheets. From the mechanical standpoint, narrow spacing (24 inches or less) is recommended.

SIZE OF COPPER SHEETS

Copper sheets are stocked in widths that are multiples of 2″. If battens of the above types are used, the width of the sheets should be 3 inches greater than the distance from center to center of battens.

Example: If the rib is 2″ x 2″ and the spacing of ribs 21″ center to center, the width of the sheet required is 21″ less 2″ (width of one rib), plus 4″ (turn-up of sheet against two ribs), plus ½″, plus ½″ (allowance for two locks) which equals 24″. (See **Fig. 26.**)

The recommended weights of sheets is: for widths between battens up to 20″, use 16-ounce; for widths over 20″, use 20-ounce.

The standard length of sheets is 96 inches. They can be had with or without transverse edges tinned. It sometimes is advisable, where the cross seams must be soldered on long runs, to cut the sheets in half and use 4-ft. lengths, thereby introducing additional seams which act as stiffeners. Cross seams in adjacent bays should be staggered, and alternate bays started with half-length sheets.

STANDING SEAM ROOFING

Standing seam construction, where the use of solder is at a minimum, is without doubt the simplest, most economical, and therefore the best way to apply sheet copper as a roofing material. Most of the old copper roofs, that count their life in centuries rather than years, are laid with standing seams. Its use is recommended.

In standing seam roofing the sheets or pans are joined along their long sides with vertical seams about an inch high. These seams break up the roof area, and give an attractive ribbed appearance, although less marked than in the batten type. In general, standing seam roofing is applicable to the same type of structures as the batten type, and can be used effectively on smaller buildings.

Standing seam roofing can be laid on slopes as low as 2½″ per ft. Since the standing seams are not soldered, they allow for lateral movement of the sheets, but are not leakproof if water can back up over them. This might happen in severe climates, where deep snow that turns to ice builds up dams that prevent the water from running off during a thaw.

FLAT-SEAM ROOFING

Flat-seam roofing is not used only, as its name may imply, on flat decks or flat roof areas, for it is adaptable to all kinds of surfaces. Steep surfaces and vertical walls are often sheathed with copper sheets joined by flat seams, and the warped or curved surfaces of spires, domes, cupolas, etc., are usually so covered because the small sheets can be varied in shape and size to fit curvature and pattern.

METHOD OF LAYING BATTEN SEAM ROOFING

Fig. 25 shows the batten seam method. **Fig. 26** illustrates the steps in forming the batten seam. **(1)** Cleats of 16-oz. copper, 2″ wide, are nailed to the sides of the battens. They should be spaced from 8″ to 12″ apart, secured by two nails, with ends of cleats turned over to cover nail heads, and so placed that they project 1″ above the batten top. **(1A)** To avoid splitting the battens, the cleat is sometimes made as a strip passing under the batten and nailed to the roof. **(2)** Copper sheets are placed between battens against and under the cleats. The long edges have been turned up at right angles for the batten height, and the final ½″ folded to form a horizontal flange. **(3)** The sheets are secured by turning the ends of the cleats down and back to engage the edges of the sheets. **(4)** The batten is covered with a copper cap, 8′ long, the edges folding back on themselves to engage the edges of the sheets. **(5)** With the caps in place, the edges are dressed against the batten, forming ½″ lock seams.

The usual way of preparing and placing the sheets is called the *Pan Method*, because the individual sheets after forming are known as "pans." Sheets 8′ long are formed as in **Fig. 26,** in the shop. These pans are then set between the battens on the roof, starting at the lower edge. They are secured by cleats spaced 12″ apart and locked together with unsoldered lock seams. The flat sheets are tapered 1/16″ on each long side so the lock of the upper pan will fit smoothly into that of the lower. The under side of the bottom edge is sometimes notched at the corners to facilitate locking, but this practice is not recommended. On roofs with a slope of 6″ or more per foot, ¾″ unsoldered loose-lock seams are satisfactory. (See **Fig. 27-A.**) For lower slopes, the method shown in **Figs. 25** and **27-B** should be used.

The loose-lock transverse seams shown in **Fig. 27** are made as follows:

(A)—"STEEP PITCH." The lower end of the upper pan is folded under ¾″ and is hooked into the 2″ overfold on the upper end of the lower pan. The folds are slit at the ends where they turn up against the batten. That in the ¾″-fold is 1″ away from the vertical leg or edge; the slit in the 2″ fold is made at the corner so that it can be bent up with and soldered to the vertical leg.

(B)—"LOW PITCH." The lower end of the upper pan is folded under ½″, and is hooked into a similar ½″-overfold on the upper end of the lower sheet. The folds are slit as shown, that in the upper pan being slightly notched; the slit in the lower sheet is soldered after the vertical leg has been formed.

(C)—"LOW PITCH (ALTERNATE)." The lower end of the upper pan, and the upper end of the lower pan are folded under and over ½″ as shown. The folds are cut off at the corner where the vertical leg begins, that on the upper end of the lower pan being soldered to the vertical leg. The fold on the lower pan engages cleats that hold it in place (Section **A-A**). The fold on the upper pan hooks into a 16-oz. lock strip 1½″ wide that is soldered to the lower pan, thus assuring a watertight joint.

On slopes of less than 6″ per foot, or where the head lap provided by a ¾″ seam is not enough to prevent leakage, cross seams should be soldered, or the "strip-pan" method of **Fig. 27-C** should be used.

The ***Roll Method*** is sometimes used for short runs that connect directly to the eave. Full-length sheets are flat-locked and soldered in the shop, using ½″ single or double seams, and rolled for convenient handling. These long lengths are unrolled at the job and formed with roofing tongs. Then they are set between the battens and secured as described above. The longitudinal movement is taken care of by loose locks at the eaves and by leaving the batten cap locks partly open.

The temperature at time of laying is important as allowance must be made for expansion, contraction, or both. If a batten seam roof is laid in cold weather, at least ¼″ should be left between the pans and the bottom of the battens for expansion in hot weather.

The finish of the batten at ridges, hips, valleys and eaves, or at the connection between roof areas and built-in gutters, and at flat-seam areas such as crickets, etc., is most important. The function of batten construction is to break up the roof into small units so that the expansion and contraction at any point are negligible. If the batten sections are soldered to other roof areas that do not provide for expansion and contraction, the effect of the batten construction is nullified.

SOME APPLICATION "DO-NOTS."

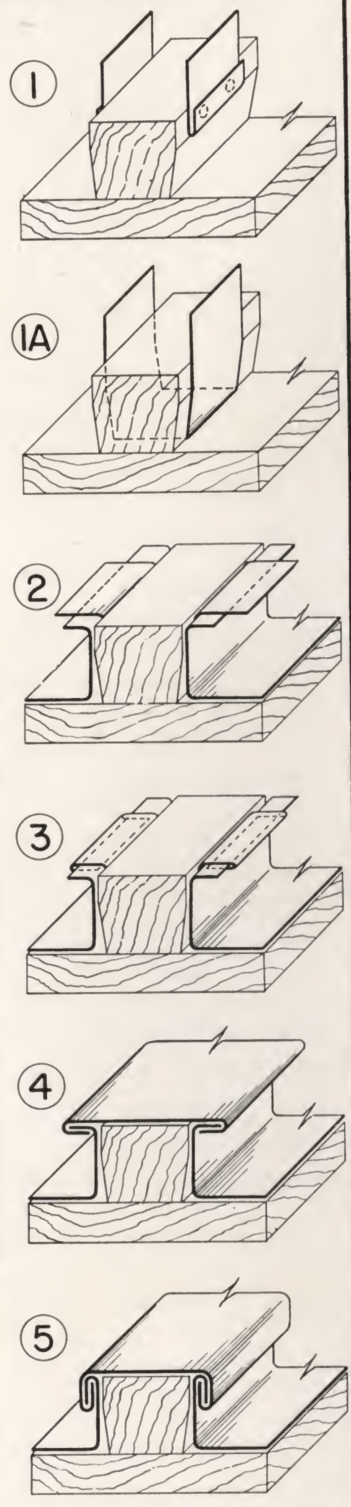
DO NOT stop the batten a few inches short of the eave or gutter edge, leaving a strip of flat soldered copper at that point. This, by fastening the roof pans rigidly together, nullifies all effect of free movement provided by the batten construction of the main roof area. Continue the batten over the edge as in **Fig. 29.**

DO NOT cut off battens a few inches before their intersection with valleys. Extend the batten over the valley metal with the batten section loose-locked to the valley, as in **Fig. 29-A.**

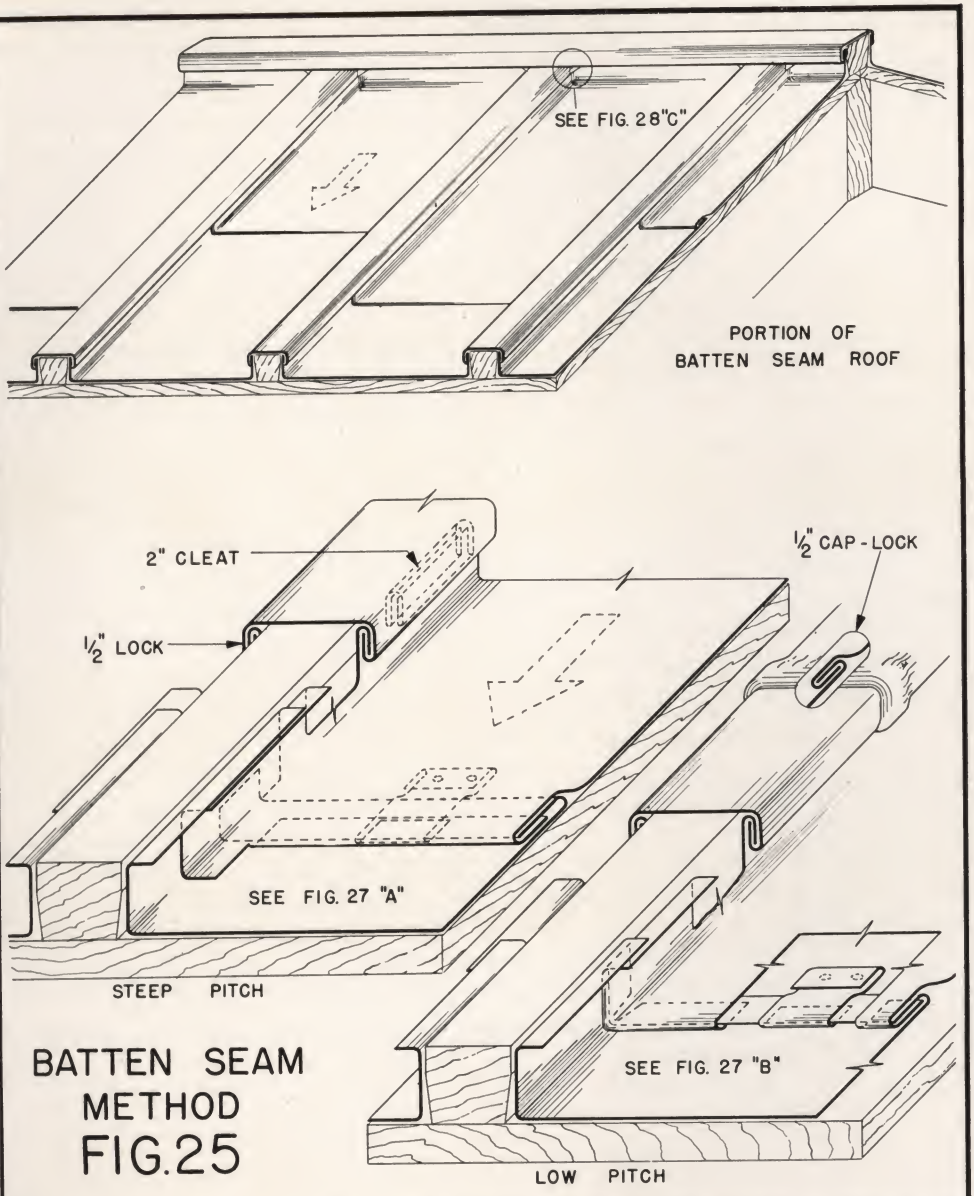
DO NOT solder batten roofing to flat-seam areas. Use a loose-lock seam (filled with white lead if necessary) with the type of construction shown in **Figs. 29-A** and **-B.**

DO NOT dress the batten pans tight up against the battens. Leave a good fillet and room for movement. See **Fig. 12** and the discussion thereof.

DO NOT use narrow single-nail cleats, and DO NOT use ferrous nails. Use wide cleats, secured with two copper, or copper-alloy, nails as shown in **Fig. 25** and elsewhere.



DEVELOPMENT OF A BATTEN SEAM
FIG. 26



BATTEN SEAM METHOD
FIG.25

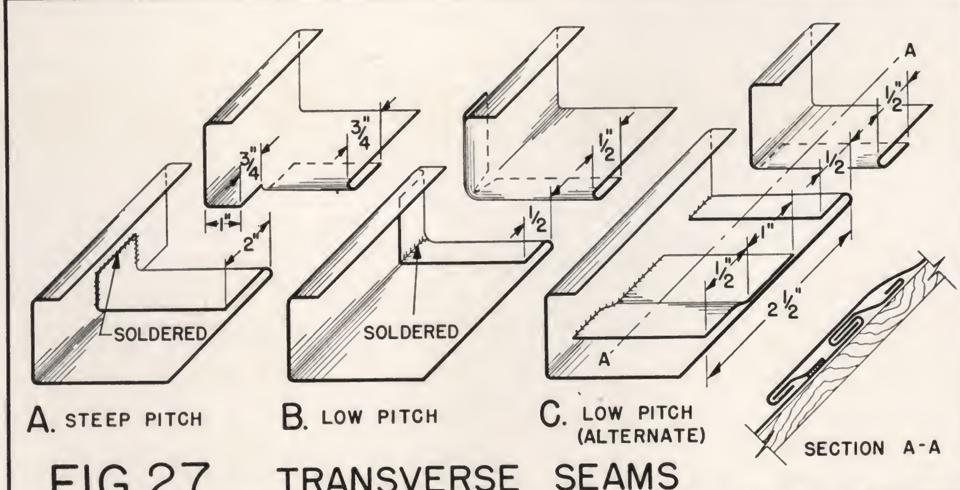


FIG. 27 TRANSVERSE SEAMS

BATTEN SEAM ROOFING DETAILS

RIDGES AND HIPS

Fig. 28 shows the construction of a batten seam ridge or hip. The ridge batten is made high enough so that the ½″ edge of its cap piece will dress down evenly on top of the roof batten. The topmost roofing pan is cut at the upper end to form a ½″ lock with the ridge cap. A pattern, as in **Fig. 31,** is usually made to insure fit, especially where ridge, hip and roof battens meet.

In the plane where the roof slope intersects the ridge batten the corners of the pans are folded down against the roof batten, as in Detail **E,** eliminating the use of solder, or are cut to form tabs which are soldered to the backside of the transverse vertical legs at the upper ends of the roof pans, as in Alternate **E.**

The steps in placing the formed sheets are: **(A)** the pans are formed and set in place; **(B)** the roof batten cap, slotted and folded to turn out about 1″ on each side along the ridge batten, is set next; **(C)** small triangles of copper are soldered to the pans and batten cap to make the corner watertight; **(D)** the ridge cap is set and the edges dressed down to form ½″ flat-lock seams.

VALLEYS, EAVES AND GUTTER EDGES

In **Fig. 29** are illustrated two ways of finishing batten-seam roofing at the lower end, where it meets valleys, eaves or gutters.

The continuous crimp in the valley sheet, to which the roof pans lock, is also used at eaves and gutter edges. In such construction the under side of the batten is sliced off at the end to let the valley sheet, or gutter apron, pass under it.

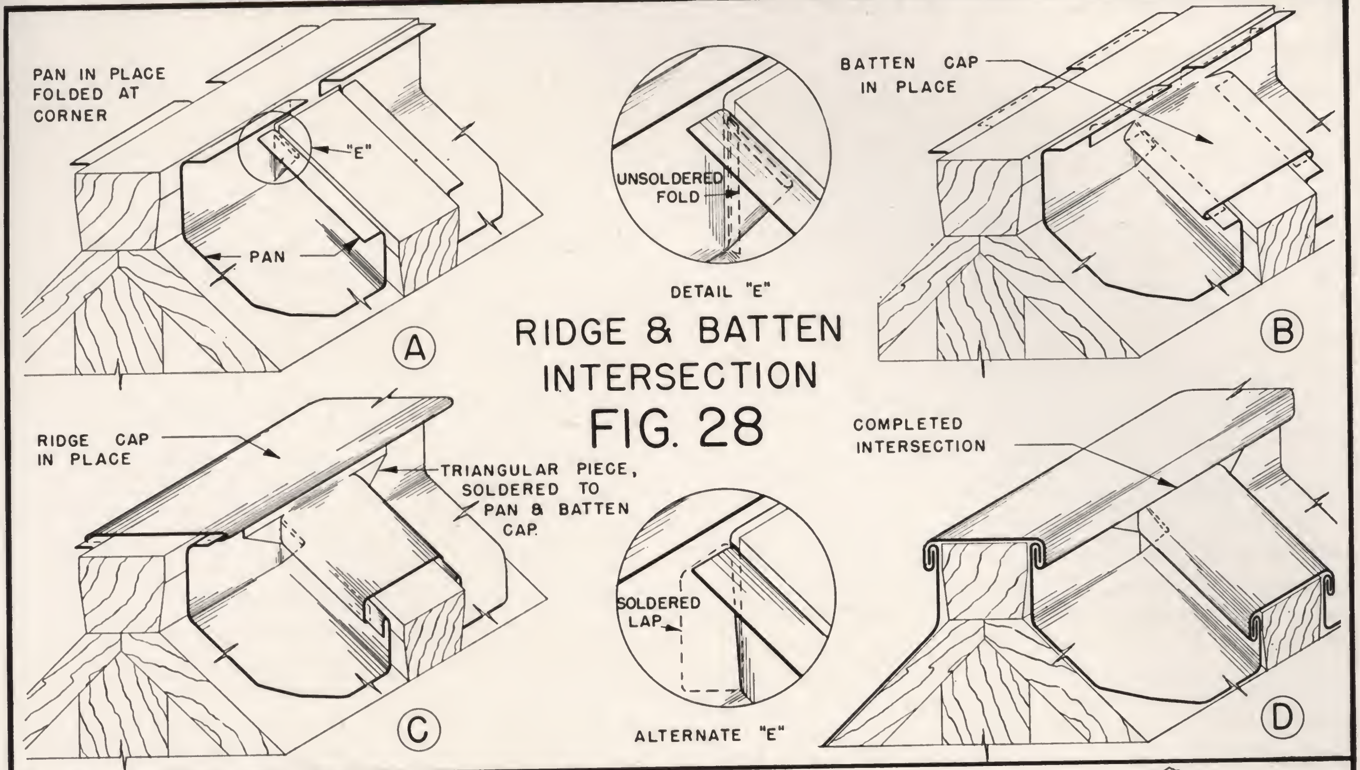
Where the design calls for the batten to end at the gutter edge, or project over it, the ends of the roof pans are turned over to form loose locks with the gutter lining, or its apron. (See **Fig. 86, Plate XXIV.**)

The forming of the sheets to develop the closure at the batten ends is shown in Detail **A.** In both methods, *soldered* and *unsoldered,* the pan is cut at the end so the vertical sides extend 1″ beyond the batten end, and the flat portion is bent under to hook into the valley crimp. End pieces, formed to fit over the batten ends, are slipped inside the ends of the two pans abutting each batten. These are made the shape of the batten, but ½″ bigger all around, with the corners cut out so that the extra ½″ of metal can be folded toward the front at the top and sides and back under at the bottom.

In the *unsoldered* method the top and bottom pieces have an additional ½″ of extra metal—as shown in the Detail **"Folded End Piece."** The 1″ tabs on the vertical sides of the pans are folded back ½″ to lock around the ½″ tabs on the end pieces. Finally, the batten cap is placed and locked to the pans as usual. The end is cut so that, for the full width of the cap, it projects 1″ beyond the batten end, and is notched to permit folding this projection under and back ½″ to engage the top flange of the end cap. The flat-lock seams thus formed are dressed tight and left projecting ½″ from the batten end.

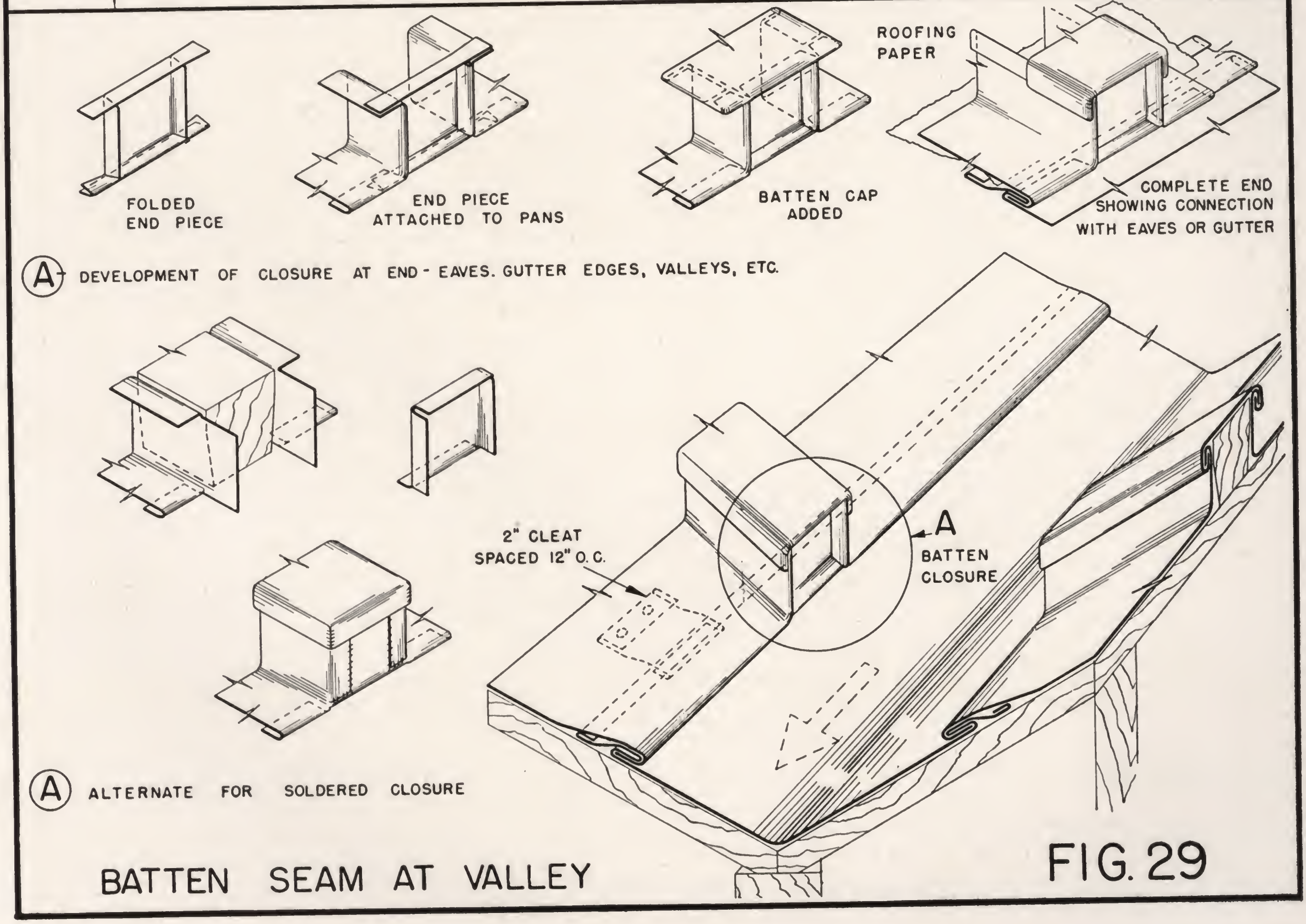
In the *soldered* method the end caps are made as shown in **"Alternate for Soldered Closure."** The ½″ locks, formed as in the *unsoldered* method, are dressed flat against the batten ends, and the seams thus formed are soldered tight.

While the *unsoldered* method is preferred, the possibility of snow and ice forming in gutters makes the use of the *soldered* method obligatory on many roofs.



RIDGE & BATTEN INTERSECTION

FIG. 28



BATTEN SEAM AT VALLEY

FIG. 29

BATTEN SEAM ROOFING DETAILS

GABLE ENDS

Fig. 30 shows eight methods of finishing batten roofing at the sides or gable ends. As will be noted the first six (wood roof support), and last two (concrete slab support), are interchangeable, selection being a matter of design and preference. While the methods differ as to details of fastening, they have two common features: a loose lock that allows the roof pan to move both crosswise and up-and-down; metal of heavier gage than the roofing pan is used for fastening.

The strips in Details **(1)**, **(2)**, **(5)**, **(7)** and **(8)** are formed from 24-oz. copper; in Details **(3)** and **(6)** 20-oz. copper is used; while in Detail **(4)** the roof pan is hooked to a heavy brass strip. The nails or screws that hold these strips are placed not more than 12″ apart.

Details **(1)** and **(2)**, which use battens along the gable end, have the advantage of preventing roof water from dripping over the edge. If a thin-edge finish is wanted. drip edges are provided as in **(3)**, **(4)** and **(6)**, though, of course, there is always the possibility of dirt-streaked walls when such gable finishes are used. Additional information on drips and edge strips will be found in **Fig. 35, Plate V,** and on **Plate XVIII.**

Detail **(1)** can be used where the roof joins a metal cornice, but with the nailing shown the cornice must be narrow (less than 12″) or made up of sheets loose-locked together to take care of expansion and contraction. In **(3)**, the roof pan is shaped for spring action and nailed to the under side of the sheathing. if the last batten is not more than 12″ from the edge. Otherwise a flat seam filled with white lead is inserted (as shown).

When the gable is capped with a stone coping a strip of 24-oz. (or heavier) copper is set in a reglet, and to this the pan is locked, as in **(8)**, by a standing seam when the roof and coping are level. Or, as in **(7)** where the roof is lower than the coping, the latter is covered with a copper strip, fastened to the reglet strip by a standing seam, and turned down to loose-lock with the roof pan.

Note that the standing seam is turned away from the reglet so that the latter can be easily caulked with lead wool. If it is expedient to turn the seam the other way the reglet is caulked before the seam is formed. For other types of reglets see **Figs. 97** and **98, Plate XXVII.**

Details **(7)** and **(8)** show the batten held by an expansion bolt to a concrete slab. Such bolts are brass and are let into lead expansion shields about 2 feet apart. On gypsum roofs the bolts extend through the slabs, and large copper or lead washers are placed between the nuts and the slab to keep the bolts from pulling through.

WALL FINISHES

Fig. 31 shows methods of finishing batten roofing against wall or parapets.

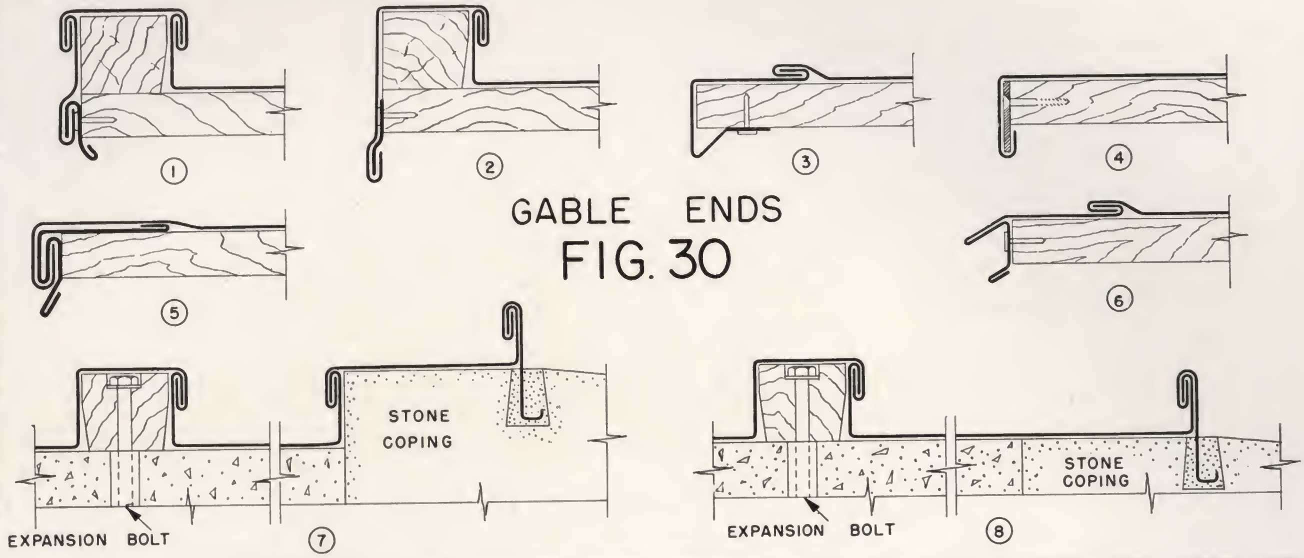
At the right is a side wall against which the last pan is turned up at least 6″ to act as a base flashing, and is held down by long cleats nailed to the sheathing at the base of the wall about 12″ apart. Cap flashings are stepped up the wall as required by the roof slope to lap the base flashing at least 4″. They extend into the brickwork as described in **Fig. 36, Plate V,** and have a side lap of at least 3″. If inserted after the wall is built they are held with lead plugs 1″ wide spaced 8″ to 10″ apart, as described on page 68. Note the ½″ fold for stiffness along bottom edge. If, by their location and size, cap flashings seem likely to be lifted by wind, heavy brass straps, or brackets extending down over each flashing, can be anchored into the masonry at intervals up the roof.

When a batten roof slopes down from a wall, one type of construction is shown in Detail **A, Fig. 31.** The pan sheets are slit at the corners so they can be turned up against the wall as well as against the battens in the usual way. They extend up the wall the height of the battens with ½″ of additional metal to form a lock with the wall sheathing. The construction is similar to that of **Fig. 28** in many details. The tabs (shown dotted) are folded against the backs of the ends of the pans and soldered. Instead of soldered tabs it is also possible here to use the fold-back corner shown in **Fig. 28,** Detail **E.** When the batten cap is placed **(Step 1)** it has an extra ½″ at the upper end. the width of the batten top, which is folded down to form a hook. Finally, the wall sheathing, which has a continuous ½″ fold along the bottom edge, is locked into the pans and batten caps **(Step 2),** and the seam is dressed down, flat on top of the battens, and vertically against the wall, giving a wave effect at each batten. This lock should not be soldered, but can be filled with white lead if there is likelihood of leakage.

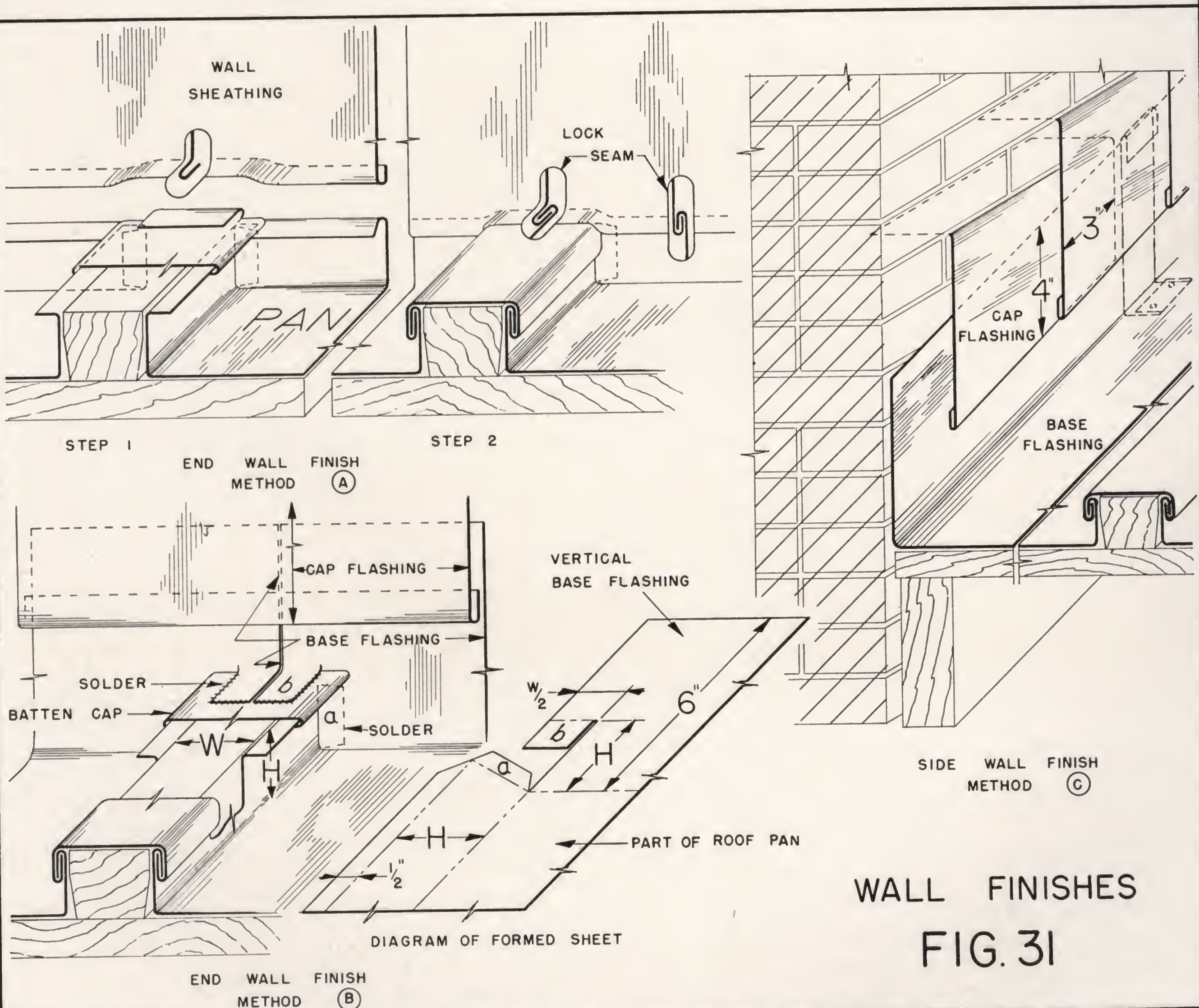
The method shown in Detail **B, Fig. 31,** makes use of a cap and base flashing finish at the wall. The pan is cut as shown at the right, so it can be folded into the corner between wall and batten, and extend up the wall 6″ as a base flashing. The lap **(a),** which is a part of the pan on the side of the batten, is folded in back of the base flashing and carefully soldered watertight. The lap **(b)** extends a short distance down over the batten, and is raised slightly to permit sliding the batten cap under it. After the batten cap has been locked in place to the flanges of the pans in the usual manner, the lap **(b)** is soldered to it around three sides, and the vertical joints between the upper end of the batten cap and the base flashing also are soldered.

The cap flashing is inserted in the masonry as described in **Fig. 36, Plate V,** except that no stepping is required, the flashing being installed continuously. Side laps between sections are at least 3″, and the cap flashing laps the base flashing at least 4″.

In long roof runs separate pieces can be inserted to form the base flashings above and lapping over the battens. Such strips are flat-locked vertically to the pan sheets forming the base flashings on each side and soldered to the batten caps. This construction allows the batten caps free movement up and down the roof slope, for they are not tied to a rigid base flashing, this now being eased by loose-locks at each batten.



GABLE ENDS
FIG. 30



WALL FINISHES
FIG. 31

STANDING SEAM ROOFING

SIZES AND SPACING OF SEAMS

Standing seams usually are made to finish 1″ high. The spacing of the seams is a matter of scale and architectural effect. For economy a choice should be made that will use sheets of stock widths—multiples of 2″. Design using 20″ x 96″ sheets is recommended as maximum for ordinary purposes.

SIZE OF COPPER SHEETS

For standing seams to finish 1″ high, the sheets have to be 3¼″ wider than the seam spacing. Accordingly, a sheet 20″ wide would give a seam spacing of 16¾″. Pan widths for various spacings and heights of seams are listed in **Fig. 34.**

The manner of forming a standing seam is illustrated in **Fig. 9,** page 19, and explained in the text describing it.

If a ¾″ finished seam is desired, the edges are bent up 1″ and 1¼″, respectively, and the seam spacing will be 2¼″ less than the sheet width.

The recommended weights of sheets is: 16-ounce for widths between seams up to 20″; 20-ounce for widths over 20″.

Standing seams are never riveted or soldered, as this does not allow movement of the sheets. Cross seams are left unsoldered whenever conditions permit.

LIGHT-WEIGHT SHEETS

The roofs of small houses, where the seam spacing need not exceed 13¾″, are sometimes covered with 10-ounce, cold-rolled copper sheets, using standing seams finishing ¾″ high. The maximum size of sheets is 16″ wide by 72″ long. They are applied in the same way as the heavier, larger sheets described here.

METHOD OF LAYING

Figs 33 and **34** show methods of laying standing seam roofing. As stated on page 27 the roof surface must be smooth and dry and without protuberances. If the surface is other than wood, nailing strips are preferred, although 2″ cut nails will hold in gypsum.

Pans 96″ long or less (preferably 48″), tapered lengthwise and with long edges turned up 90°, are set in place starting at the eaves, transverse seams being staggered. Cleats 2″ wide and 1½″ longer than the lower vertical edge, are nailed to the sheathing 12″ apart, as in **Fig. 33,** and the lower edge of the pan is set over and against them. The last ¼″ of the cleats is bent over to hold this edge. The side of the next pan having the high edge then is put in place against the cleats, and the extra ¼″ bent over, as shown. Finally, the top ½″ of the whole seam is folded over again through 180° to form a double-lock.

A double or split cleat (**Fig. 33**) is also used. This is cut unevenly at one end and notched in the center so as to fold down ¼″ in opposite directions over the vertical sides of both pans.

Fig. 33 shows a common method of assembling the pans. Cross seams are ¾″, loose-locked and secured with at least two cleats. To avoid too many thicknesses of copper at the standing seam the corners at the top of the pan are cut away as shown in detail **B.** White lead and linseed oil should be used to fill these seams if there is any likelihood of excess moisture. The ½″ flat lock, shown in **Fig. 27-B, Plate I,** is also commonly used on steep slopes where water cannot back up. On roofs with slopes of 6″ or more per foot the cross seams are sometimes big loose locks, formed as shown in **Fig. 27-A, Plate I.**

Fig. 34 shows another method of laying, using sheets preformed in the shop. One edge of each sheet is folded twice, as at **"A"**, and the other three times, as at **"B"**. Each sheet is cleated along the edge with the **"A"** fold, as shown at the right, and the **"B"** edge of the next sheet laid in place over the cleats. The extra ¼″ at **"B"** is then folded under, and the two joined edges are finally turned down 90° to finish the seam. This method reduces work on the job and gives accurate and even seams.

Steps 1, 2 and **3, Fig. 33,** illustrate one way of making the standing seam watertight at the eave—or gutter edge—when it is not folded under as in **Fig. 37, Plate V.** The ends of the pans are slit and trimmed so that on the higher flange there is a 1″ or 1¼″ tab. This is folded back against the lower flange and tack-soldered to keep water out. Note in **Step 3** how, as the seam is turned over to form the lock, the tab folds into itself at the end to make a watertight joint.

As in batten seam roofing, the sheets can be formed and handled by the "roll method" described on page 36. The cross seams are made ½″ double-locked or ¾″ flat-locked, and are left unsoldered. On flat slopes white lead and linseed oil is used to keep out water, if the roof is not free-draining at all times.

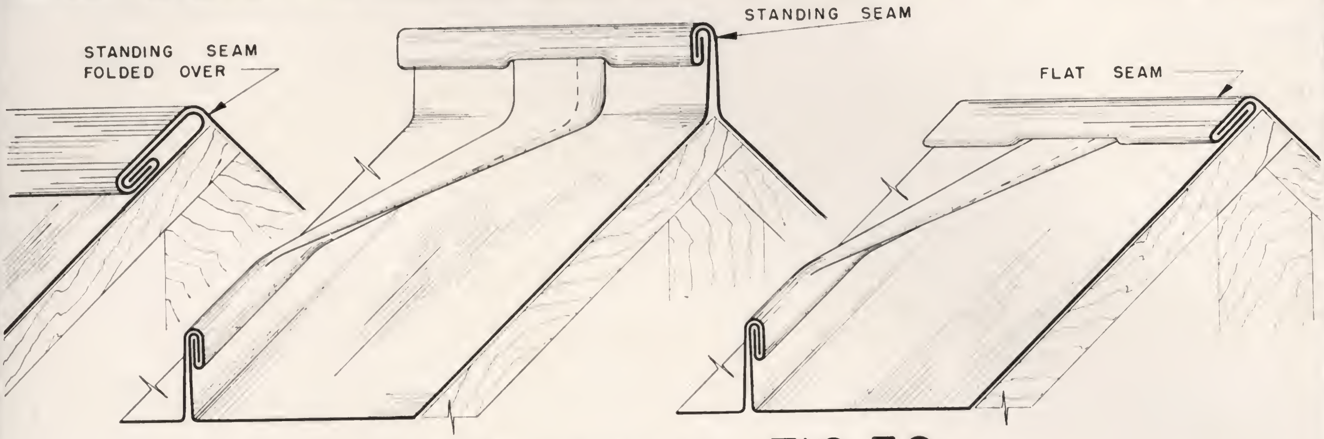
It is important to consider the temperature at the time of installation, and make proper allowance for changes. In standing seam roofing, expansion can be allowed for by leaving a space at least ⅛″, at bottom of seam. This detail and adequate fillets are both important.

STANDING SEAM ROOFING DETAILS

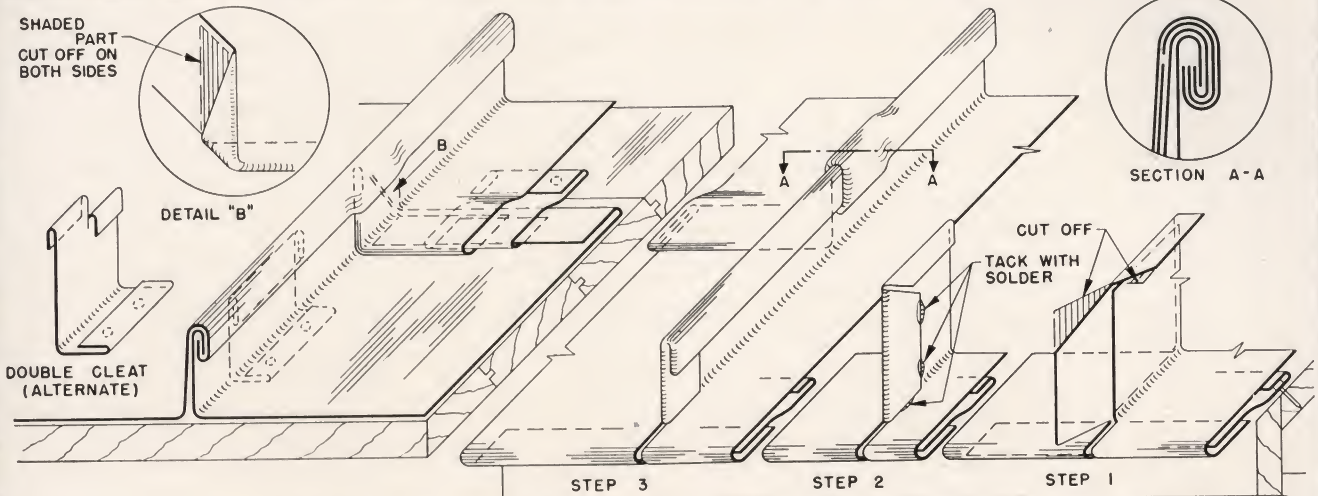
RIDGES OR HIPS

Fig. 32 presents 3 ways of finishing the ridge or hip of a standing seam roof. The pans from the two sides can be brought up beyond the ridge ¼″ higher on one side than on the other, and a standing seam formed. Or this seam can be folded down flat as shown on the left. The seams of the roof slopes are turned down as they approach the ridge and folded into the ridge seam. Ridge and hip seams generally finish the same height as those on the slopes.

In place of a standing seam, a flat-lock seam can be used, as shown on the right. Here the roofing seams are turned down flat and folded in with the ridge seam. On one slope (as shown) the flattened standing seams run into the ridge seam, and from the other they are carried over the ridge and down into the ridge seam.



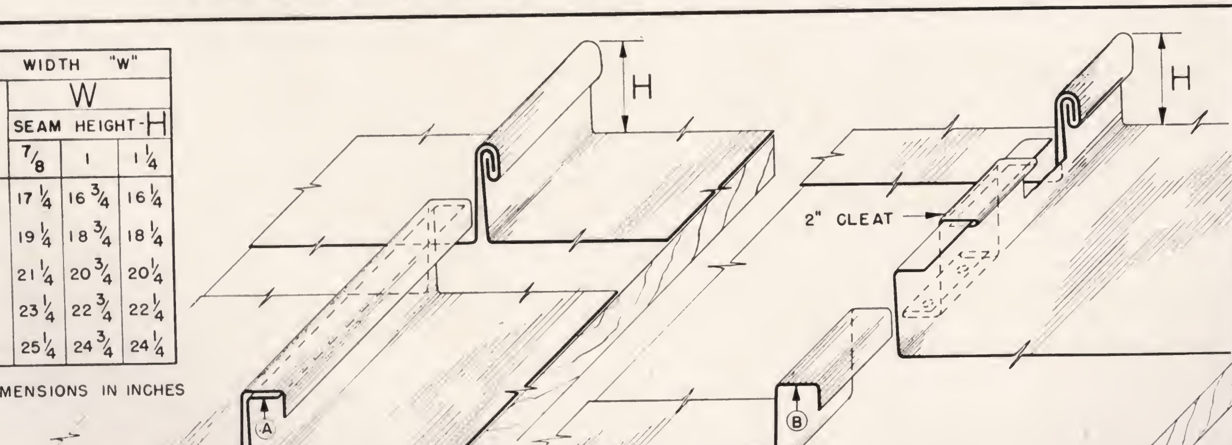
RIDGE DETAILS FIG. 32



TYPICAL BAY - STANDING SEAM METHOD FIG. 33

PAN WIDTH "W"			
WIDTH OF SHEET	W		
	SEAM HEIGHT - H		
	7/8	1	1 1/4
20	17 1/4	16 3/4	16 1/4
22	19 1/4	18 3/4	18 1/4
24	21 1/4	20 3/4	20 1/4
26	23 1/4	22 3/4	22 1/4
28	25 1/4	24 3/4	24 1/4

ALL DIMENSIONS IN INCHES



TYPICAL BAY - PREFORMED PAN METHOD FIG. 34

STANDING SEAM ROOFING DETAILS

GABLE ENDS

Fig. 35 shows 3 methods of finishing standing seam roofing at the gable of a roof. All three details provide drips to prevent the roof wash from running down the face of the building. The cleats in Detail **(3)** are spaced 8″ to 10″ apart. End finishes **(3), (4), (5)** and **(6)** for batten seam roofing **(Fig. 30, Plate III)** can be also used with this method as can any of the plain edge strips illustrated in **Fig. 79, Plate XVIII.** Detail **(1)** of **Fig. 35** is preferable, because it forms a curb along the gable.

WALL FINISHES

In **Fig. 36** the righthand detail shows a method of finishing standing seam roofing against a vertical wall at the high end of the roof, using cap and base flashing. The roofing is carried up close to the wall, with room allowed for cleating. The base flashing is locked into the seam over the cleats and the standing seams are folded down, with the open side underneath, and carried into the flat-lock seam, which is tack-soldered. The base flashing is carried up the wall at least 6″ and lapped 4″ by cap flashing.

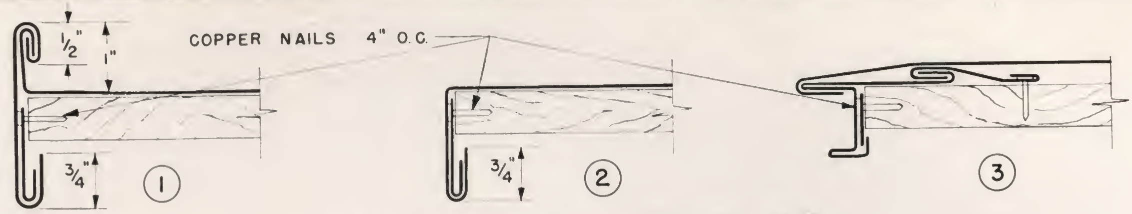
The cap flashing is continuous, with unsoldered 3″ laps between sections, and the bottom edge is folded back ½″ for stiffness. If installed as the wall is erected the cap should be anchored back of the first brick. If placed after the wall is erected, it is fastened with lead plugs. (See page 68.)

The lefthand detail shows a method of sheathing a vertical wall by using standing seams. The seams are carried to the top of the wall where they are joined by loose-locks to the through flashing under the coping (Detail **A**). At the bottom they are folded to turn under the lower edge, which is formed by a ¾″ turn-back. (Detail **B**). Such vertical sheathing is used when it is necessary to waterproof the entire wall above the sloping roof.

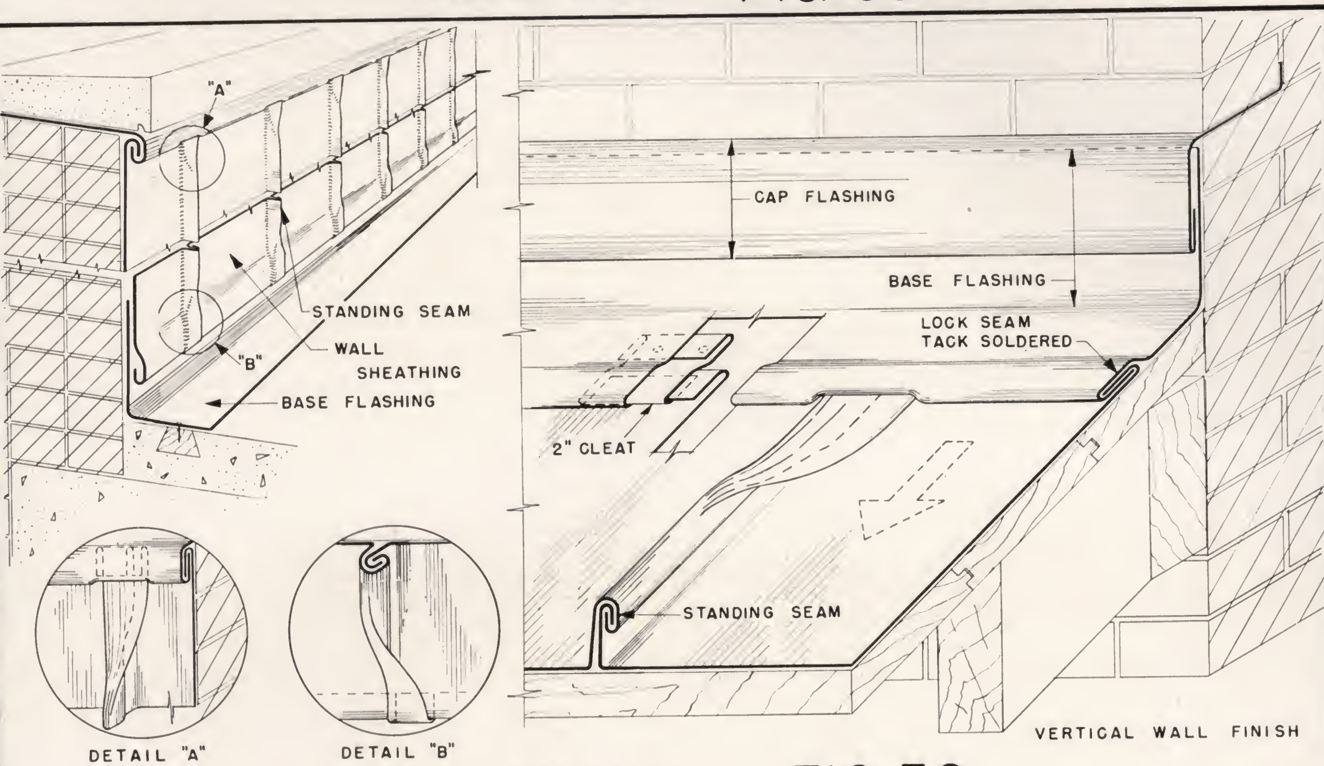
HIPS AND RIDGES

Fig. 37 illustrates how hips and ridges, and their intersections, are made watertight without soldering. Standing seams are formed along the ridge (and hips), and the seams joining the roof pans are flattened and locked into them, the ½″ fold of the standing seam being turned under at the ridge so that water cannot work its way through it. At the eave, however (or valley, as in **Fig. 38, Plate VI**), the ½″ fold is kept on the top so that water running down the roof pan flows over instead of into it.

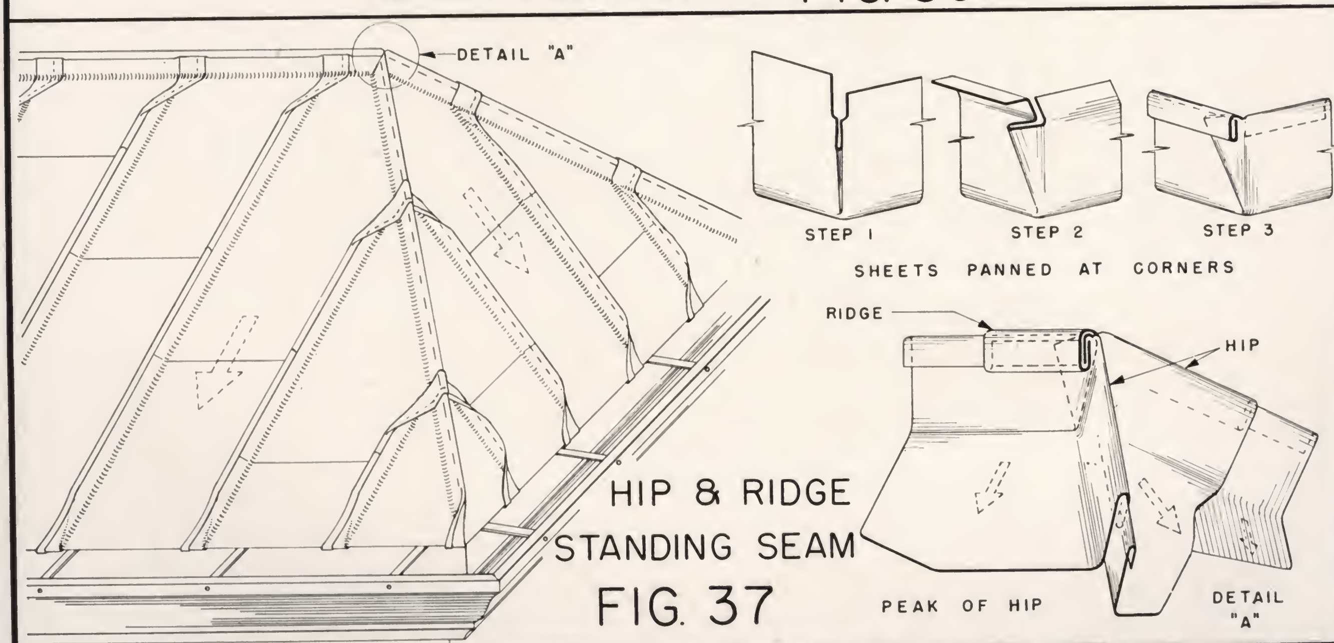
Detail **"A"** shows how the sheets at the peak where ridge and hips intersect are notched and folded together into a watertight joint that does not require any solder, and provides room for the copper sheets to move under thermal changes or because of settlement or shrinkage of the supporting structure.



GABLE ENDS FIG. 35



WALL FINISHES FIG. 36



HIP & RIDGE STANDING SEAM FIG. 37

STANDING SEAM ROOFING DETAILS

VALLEYS

Fig. 38 shows standing seam roofing at a valley. While the usual method of folding standing seams is as shown in **Fig. 37,** at the intersection with valley linings the seams are folded down the slope of the roof so that smaller pockets are formed. They can also be finished as shown in **Fig. 33, Plate IV.**

The folded seams, and the ends of the pans, hook into the valley lining. If the "preferred method" is not used the seam must be soldered its full length to make it watertight. The valley flashing is held to the roof surface with the usual 2″ cleats, spaced about 12″, and secured with 2 nails.

EAVES

Fig. 39 shows three ways of finishing standing seam roofing at eaves and gutters. The standing seams are folded over (with seam opening on top) as they approach the eaves so they can be folded into the joint with the gutter or over an edge strip. The gutter lock can be placed on the roof slope, as shown at the left, or at the top of the inner side of gutter, as at the right, provided the gutter is designed so its outer edge is at least 3″ lower than this seam, which must be left unsoldered to allow the gutter lining to move. The loose-lock seam where roof and gutter meet may be filled with white lead to prevent water entering from capillary attraction.

At the eave the edge strip is formed as suggested in the upper righthand detail.

SOME APPLICATION "DO-NOTS"

DO NOT solder cross seams (see **Fig. 33**)

DO NOT solder standing seam areas to gutter linings. (see **Fig. 39**)

DO NOT solder standing seam areas to valleys. (see **Fig. 38**)

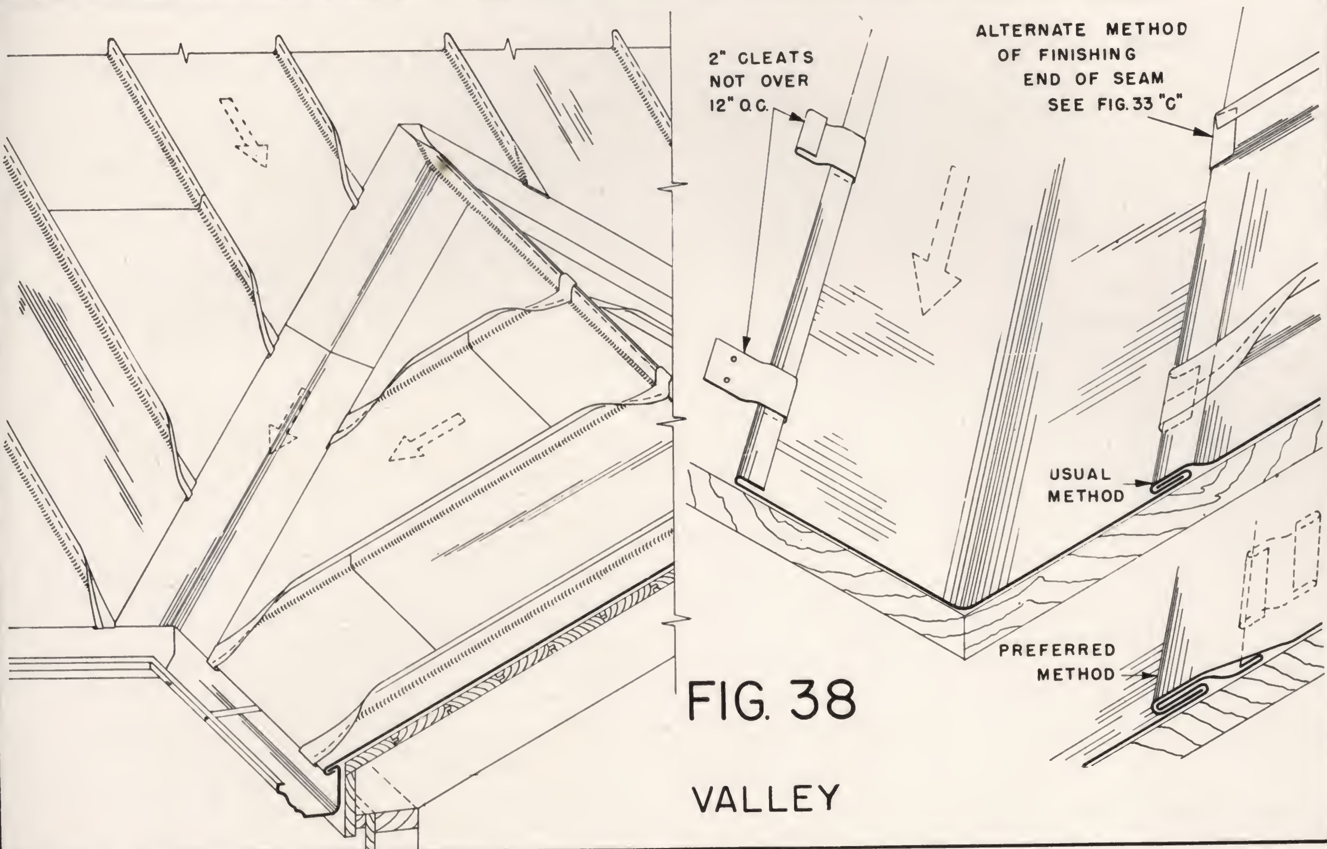


FIG. 38

VALLEY

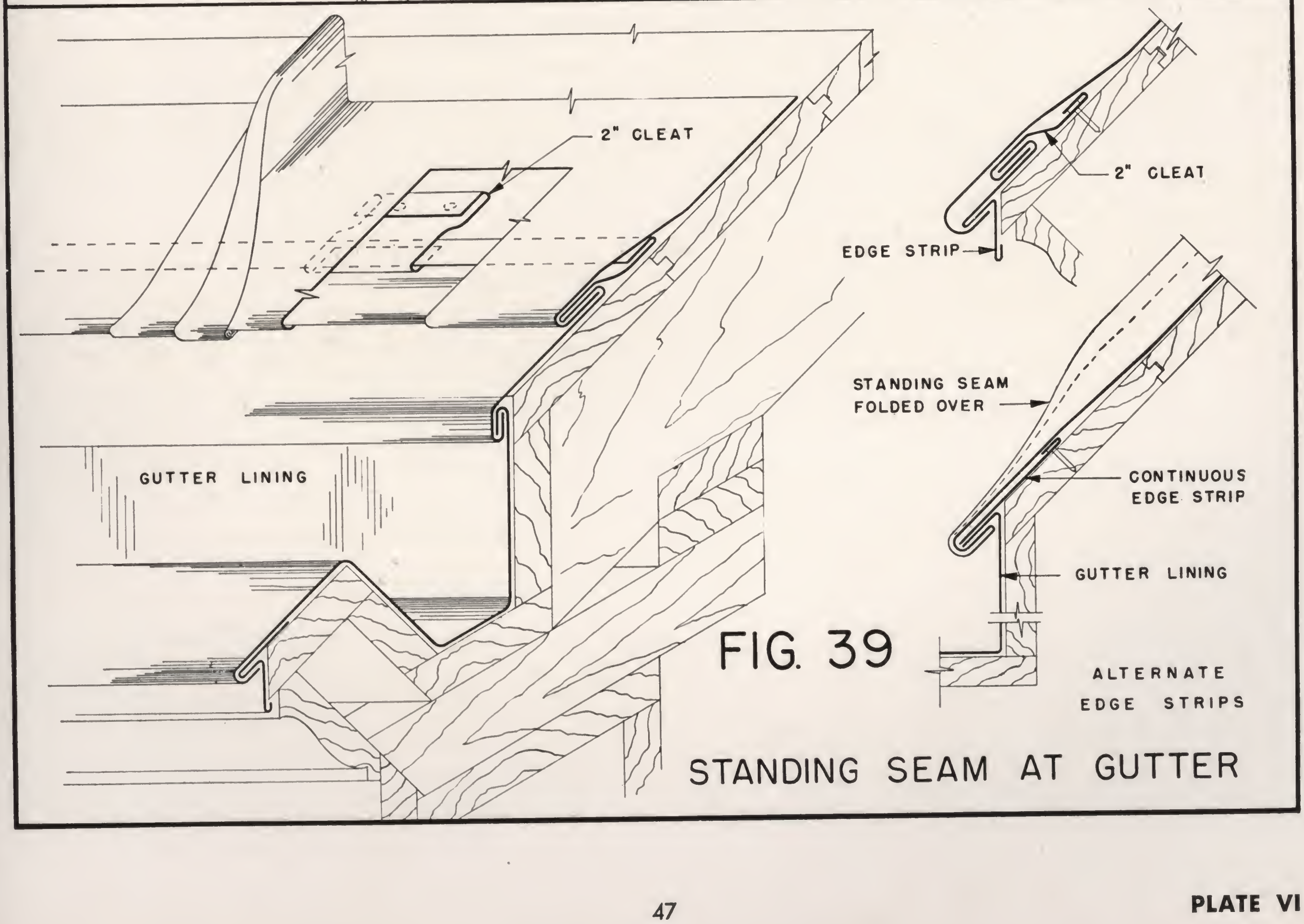


FIG. 39

STANDING SEAM AT GUTTER

FLAT-SEAM ROOFING

SIZE OF SHEETS

Small sheets of 20-oz. cold-rolled copper, not larger than 16″ x 18″, with ¾″ seams flat-locked and soldered, are recommended. If there is no possibility of water collecting on the roof, because of clogged outlets, or ice and snow, the seams can be left unsoldered and filled with white lead. But this construction is rarely used, except on domes or steeples.

METHOD OF LAYING

Fig. 41 illustrates the method of laying flat-seam roofing. The sheets are tinned on all edges, for soldering, and then are formed to lock ¾″ with adjacent sheets, the seam being the flat-lock described in detail on page 18. The corners must be clipped to permit folding, as shown at the left. Opposite sides of the sheets are folded in opposite directions so they will hook into the adjoining sheets.

The sheets are held down by 2″ copper cleats, two on each of two sides. For small areas it is general practice to use but 3 cleats, two on one long side and one on one short side. The other two sides are held by the edges of adjacent sheets already cleated.

The cross seams are folded in the direction of flow. All seams should be flattened with a mallet before soldering, and then the solder sweated in to fill the seam completely.

EXPANSION AND CONTRACTION

Movement due to temperature changes is of special significance in flat-seam work. The batten and standing seam methods, in which the longitudinal seams are unsoldered, permit lateral movement between seams, and movement in the direction of the roof slope.

The flat seam method, however, does not allow free movement, and yet such installations do not break. Many theories have been advanced to explain this. Recent laboratory investigations indicate that what happens is somewhat as follows:

Each small piece, being held by eight cleats and stiffened by soldered seams on some 23% of its area, acts as an individual unit and absorbs its own thermal stresses. Moreover the restraining action of the cleats on four sides tends to disperse the stresses evenly in all directions. Under expansion each sheet buckles slightly, the total lengthening of an 18″ sheet through 170° of temperature change being but 0.04 inch. Under contraction (always much less than expansion) the cleats confine the tension to each piece.

However, this apparent localization is counteracted by other potent agents. As each sheet is locked and soldered to the adjoining ones there is thus created a continuous expanse of copper subject to cumulative and unevenly distributed stresses as the sun moves across the heavens on a hot day. And as a few cleats are certain to yield under the strain, the forces thus released build up until enough cleats are torn loose to allow sufficient movement to create critical buckles and to tear seams

Calculation of the forces at work shows that roof areas to be covered with flat-seam roofing should be divided into squares that can be circumscribed by a 50′ circle, and enclosed by the expansion battens as illustrated in **Fig. 42.** In actual practice the recommended size of such panels is 37′ x 36′-6″, because these will use 780 pieces of 16″ x 18″ copper, without wastage.

In this drawing is shown also the expansible intersection (Detail **A**) and its cap. The detail is clear enough to require no explanation here. Note that the copper cap is made ¾″ wider than the wood batten, which is about twice as much expansive movement as can build up from the center, where the copper is fastened in the roof drain flange, to the batten at the outer edge of the rectangle.

RIDGES OR HIPS

Fig. 40 shows two varieties of ridge finishes for flat-seam roofing. In Detail **A** a flat strip is folded over the ridge and hooked to the top row of roofing sheets. The locks on both sides of the ridge are turned up until the ridge piece is hooked under them. Then the seams are malleted flat, as shown. The roofing is locked into the edge folds, and either soldered or left loose as dictated by the slope. If movement is required, a ridge piece of the type shown in Detail **B** is used. This has a large crimp into which the top roofing sheets slide, the edges being folded back for stiffness. The under lap, which is nailed to the roof, and the ridge roll allow for movement toward and away from the ridge, without any chance for leakage. The details in **Fig. 32, Plate IV,** for ridges with standing seam roofing, also are applicable for the ridges and hips of flat-seam roofing.

GABLE ENDS

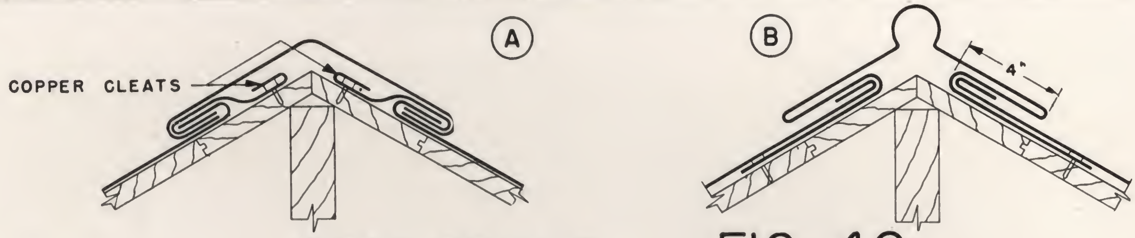
For finishing flat-seam roofing at gables see **Figs. 30, Plate III,** and **35, Plate V,** where various constructions are shown, all of which can be used with flat-seam work. Those with the edge built up have the distinct advantage of keeping the drainage on the roof at the ends of the building, and are recommended.

VALLEYS

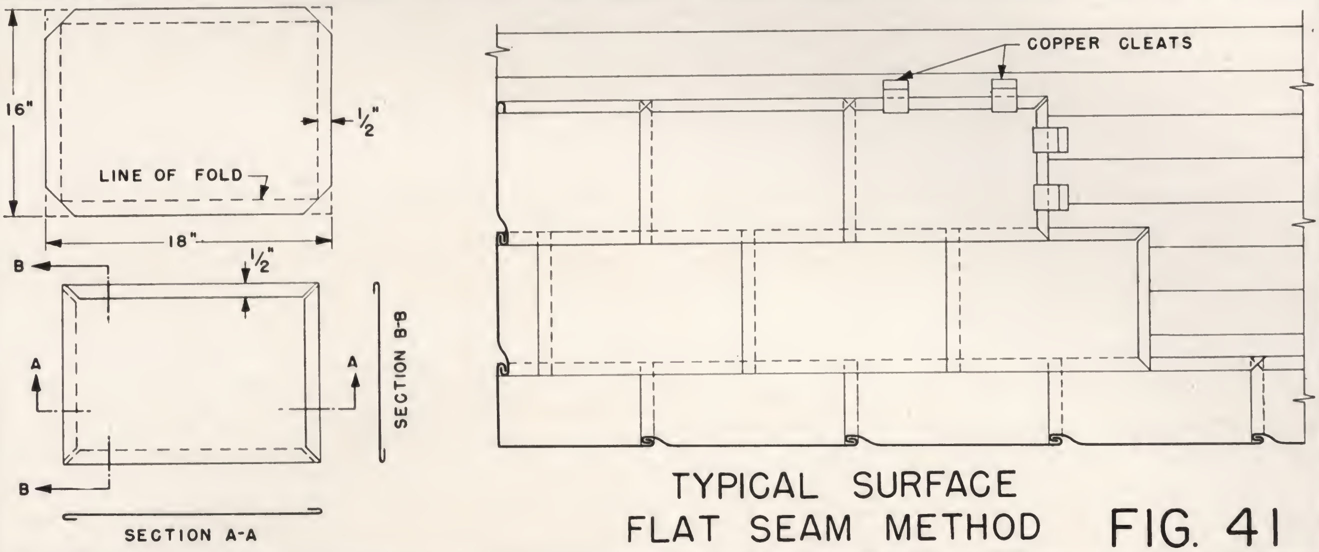
The valleys encountered in flat-seam roofing work are usually so flat that the small sheets can be shaped over the depression. But when a valley is formed of a long sheet, in the customary manner, the construction is similar to that for standing seam work, shown in **Fig. 38, Plate VI,** the small roofing sheets being locked and soldered to the edge folds of the valley. In the **Preferred Method** the valley lock is larger than that in the roofing sheet, and the seam need not be soldered.

WALL FINISHES

It is common practice to enclose flat areas with walls or parapets. The use of cap and base flashing to make the angle at the wall watertight is usually most satisfactory under such conditions. The roofing sheets are turned up against the walls at least 6″ and then lapped 4″ by cap flashings set in the masonry. On the side walls the caps are stepped from course to course as required by the slope, being inserted in the walls as the masonry progresses.



RIDGE DETAILS FIG. 40



TYPICAL SURFACE
FLAT SEAM METHOD FIG. 41

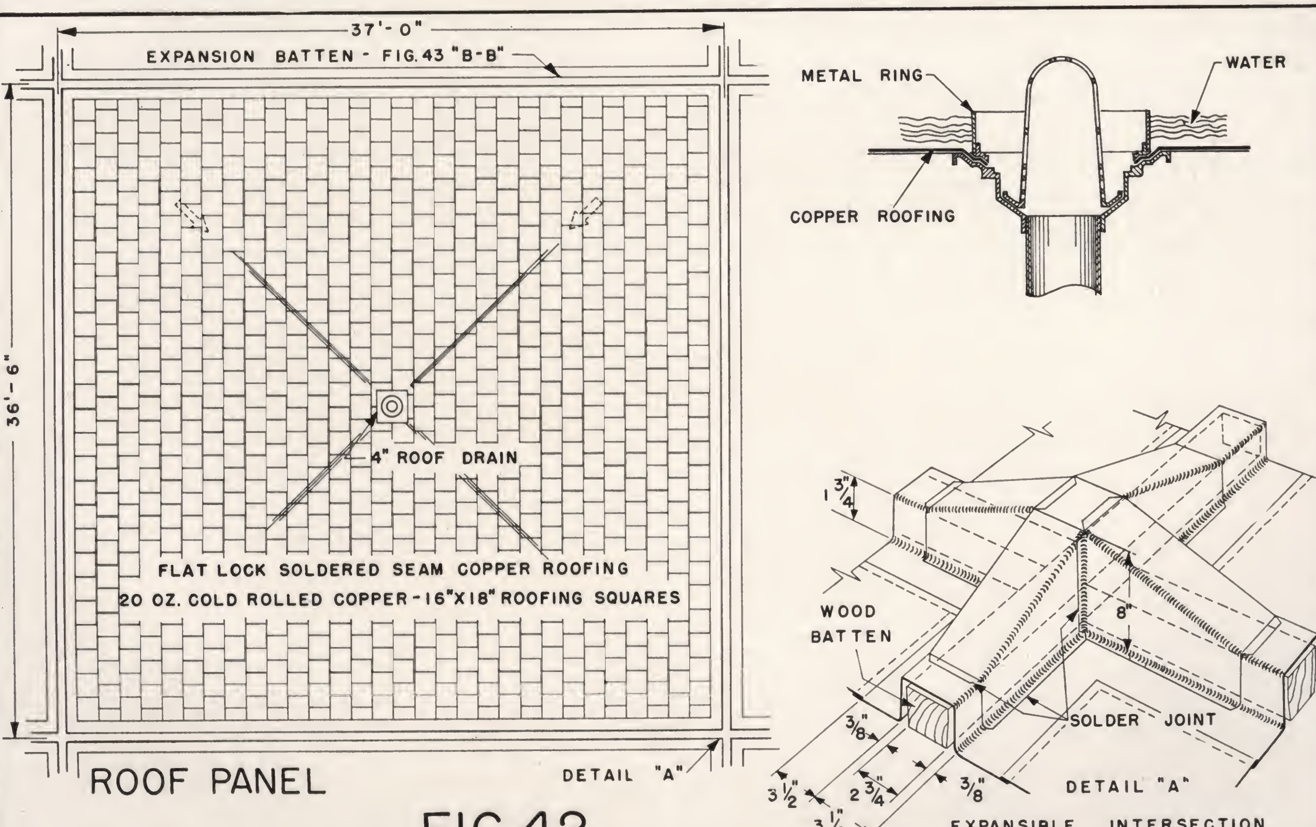


FIG. 42

FLAT-SEAM ROOFING

WATER-COOLING ROOF PANELS

The principle of cooling a building by covering its roof with a layer of water is well understood, and the practice is finding wide application, not only in the South and Southwest, but also in Northern localities where winter freezing is a problem. **Fig. 43** shows how the "panel-batten" type of flat-seam roofing described in **Fig. 42** is used to form shallow metal pans on a flat roof that will hold water and ice with no harmful effects. *No lighter than 20-oz. copper is recommended.*

The roof drain, at the centre of each panel, is set at the same level as the rest of the roof or, at most, an inch lower than the base of the expansion battens, which of course, are level in both directions. A copper pan (see **Fig. 108, Plate XXIX**), high enough to keep the water even with the batten tops, is placed around the outlet and soldered to the roof sheets. The expansion batten, shown as 1¾″ high, is usually made higher, but seldom exceeds 3″.

The panels on large areas are filled from a system of pipes and nozzles with automatic controls. A garden hose serves the same purpose for small areas. In winter the panels need not be drained (although it is always best to do so) because the ice that forms is not thick enough to cause trouble.

The eaves and roof edges are commonly finished with battens in manner similar to Details **(1)** and **(2)**, of **Fig. 30, Plate III.** They can also be made with the type of edge strip, or gravel stop, shown in **Fig. 125-B, Plate XXXIV.**

DEAD-LEVEL ROOFS

The type of roofing shown in **Figs. 42** and **43** is designed for use on dead-level roofs. These have no outlets except as may be necessary to keep rain water from flowing over the eaves onto abutting properties or where pedestrians pass. It is good practice to finish the edge panels into edge strips, or drips, that drain into hanging gutters (**Figs. 133** and **135**).

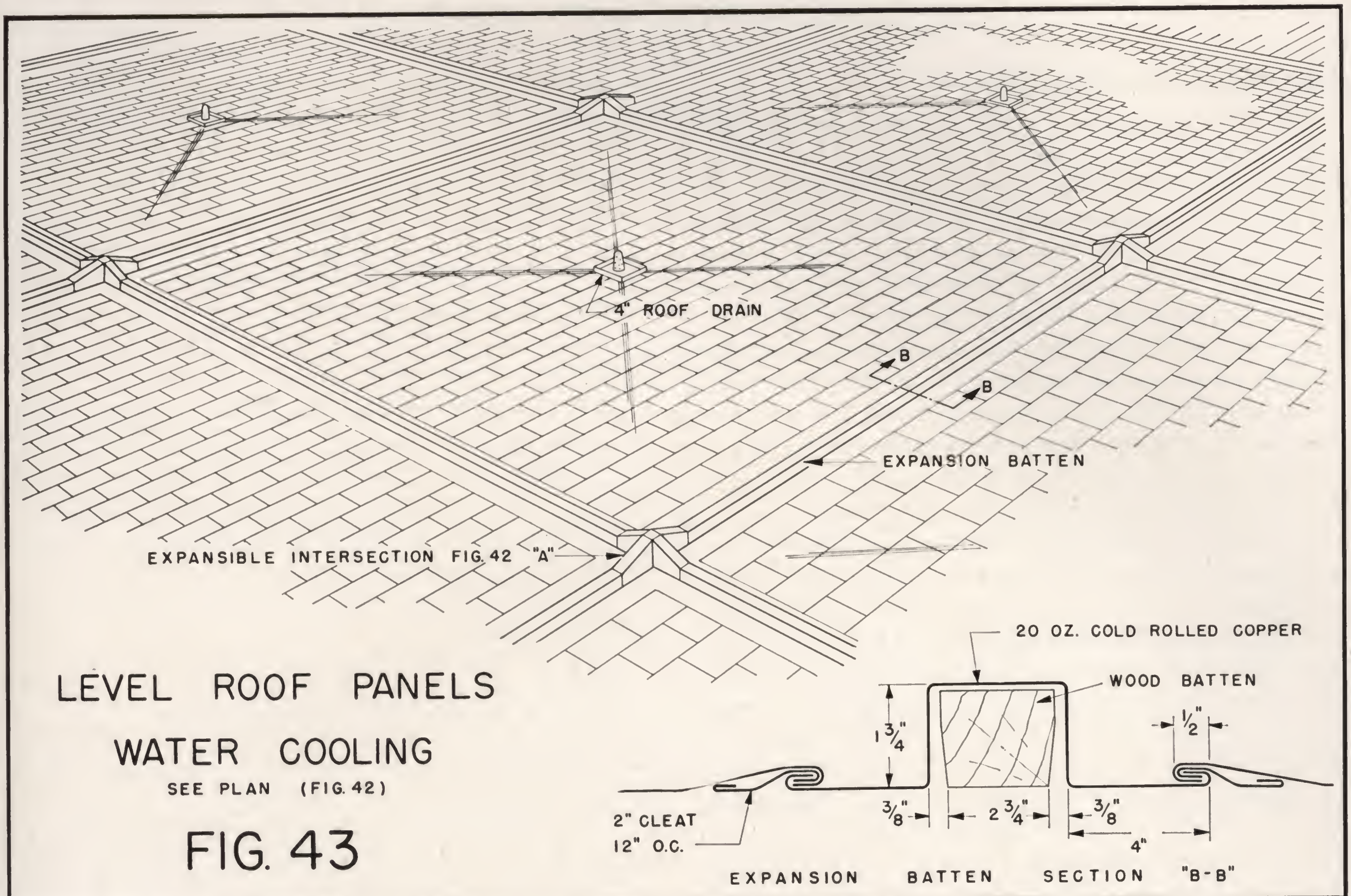
In such installations the battens usually are made 1¾″ high so as to reduce the weight of water and ice that is held on the roof by them. The small sheets of 20-oz. copper, with their cleats and ¾-inch flat-locked and soldered seams, have the strength requisite to withstand the stresses of temperature change and ice thrust.

ROOF GARDENS AND POOLS

Fig. 44 shows how flat-seam roofing is adapted to form watertight pans for the sunken gardens (and pools, too) that are built on the roofs and terraces of apartment houses in the top-rental class. The construction is the same as in **Fig. 42,** except that the sides finish against vertical walls instead of battens. In the example shown the cap-and-base flashing method is used, for the parapet is high enough to keep out roof water and the soil level is kept below the top of the base flashing. Single flashing, full-soldered, can be used so long as there is a loose-lock joint at the top of the wall, just under the coping.

If used, the centre drain is generally left open to act as an overflow in case of flash storms.

While not illustrated, it is obvious that this type of construction is admirably suited for lining the fish ponds and lily pools often built on the roofs of underground structures or in artifically-created lawns, gardens and terraces in courts, patios, lobbies, entrance plazas, etc.



LEVEL ROOF PANELS

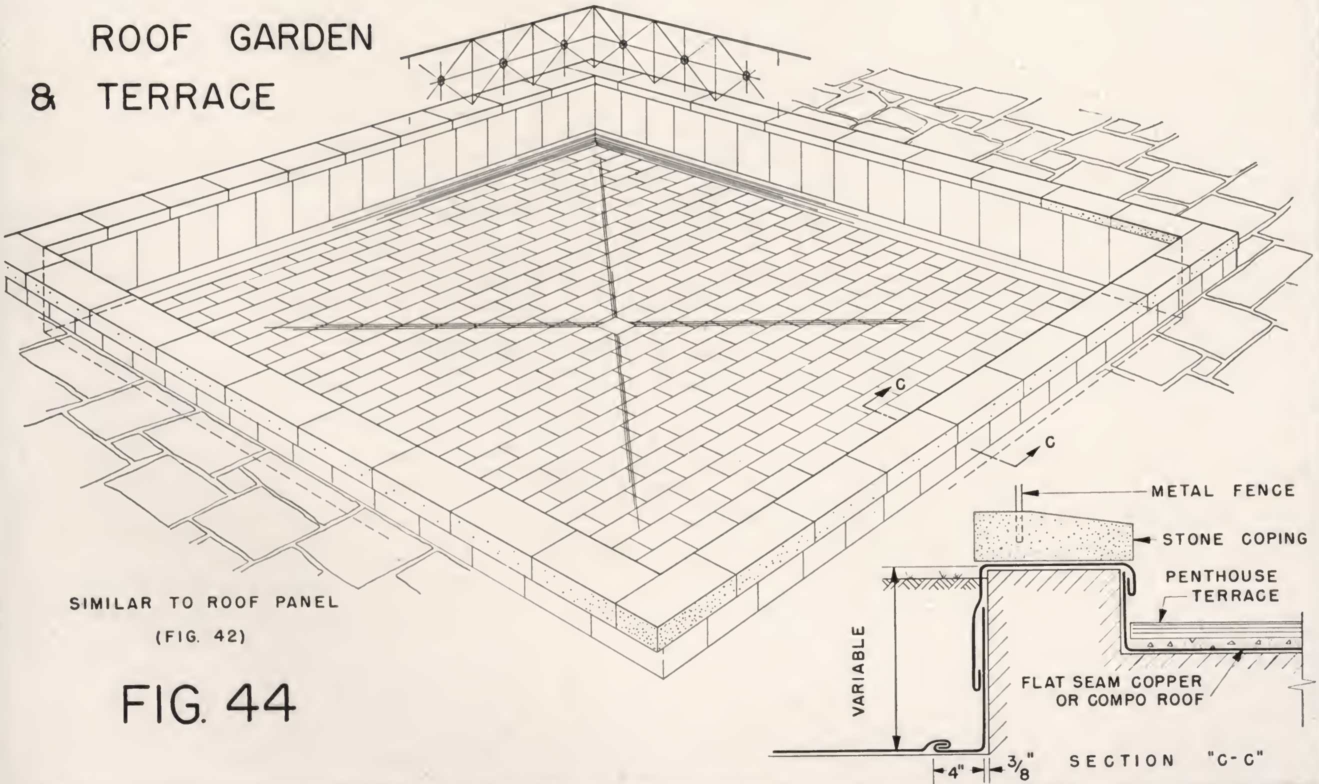
WATER COOLING

SEE PLAN (FIG. 42)

FIG. 43

ROOF GARDEN

& TERRACE



SIMILAR TO ROOF PANEL

(FIG. 42)

FIG. 44

CORRUGATED COPPER ROOFING

METHOD OF APPLICATION

Fig. 45 shows the approximate dimensions of the standard "2½-inch" corrugated sheet as used for roofing and for siding. These are the same as for steel sheets of the same gage. It will be noted that while nominally 2½″, the actual width of corrugations is 2-2/3″. Sheets with a nominal corrugation of 1¼″ are also available. This figure emphasizes again the distinction between "crimped" and "corrugated" copper, already mentioned on page 30. Actually both types are corrugated but the term "crimped" is applied to the closely-spaced, shallow corrugations illustrated in **Fig. 22**. The term "corrugated", as shown in **Fig. 45,** means the deeper, wider-spaced corrugations formed like those available in other metal sheets.

As shown in **Fig. 45,** the standard construction for roofing is 20-ounce sheets about 27½″ wide (which before corrugation was 30″) laid with laps of one-and-one-half corrugations. A two-corrugation lap may also be used, providing alternate sheets are turned upside down. The area covered is, of course, correspondingly decreased.

For siding the standard sheet is 16-oz., about 26″ wide (28″ wide before corrugation). This is laid with a single corrugation lap, so the actual coverage for both roofing and siding is 24″ per sheet. The end lap for roofing should be at least 6″; for siding 3″.

All copper corrugated sheets and accessories should be secured with fastenings of copper or copper-alloy. In roofing, these are applied through the highest points of the corrugations. Copper-alloy nails 8″ apart (every third corrugation), with lead washers, are used for securing these sheets to wood sheathing. If the sheets are to be laid over steel purlins, the purlins are insulated from the copper with lead or felt strips. Many types of fastenings have been developed, such as clinch nails, clinch rivets, straps, etc., for this kind of construction.

Corrugated roofing always is laid by starting at the end of the roof farthest from the direction of the prevailing wind, so as to lap the sheets away from the wind and thus decrease the possibility of rain driving under them.

EAVES

Fig. 47 presents one method of treating corrugated copper roofing at eaves, the latter being flashed to the siding. The roofing sheets project 2″ or 3″ beyond the edge of the roof, and the eave apron extends up under them about 2″ and is nailed. Under the roof projection the flashing is crimped to form both a drip and a pocket to receive the top of the corrugated siding. The lower end of the flashing unit is nailed to the wall sheathing before the siding is applied. Often the flashing is omitted if the wall is not sheathed with metal.

RIDGES

Fig. 48 shows a method of finishing corrugated roofing at ridges. Separate ridge units are required. A plain ridge cap is used in which the corrugations flatten out as they approach the ridge until the metal is entirely flat at the peak. The ridge pieces are secured to the purlins or nailed to the sheathing as described above.

GABLE ENDS

Fig. 47 presents one method of finishing a gable end. A batten along the edge keeps the drainage on the roof, the roofing sheets being cut so they lie against it almost to the top. The edge flashing acts as a cap flashing over the roofing and locks to the cleated flashing piece below to form an edge drip. The vertical siding fits into the pocket formed in the flashing. If the gable overhang is large, and stronger construction is required, a brass edge strip can be used (see **Figs. 30, Plate III,** and **79, Plate XVIII**).

SIDING CORNERS

Fig. 46 shows methods of finishing corrugated copper siding at external and internal corners, respectively. Corner angles of copper, formed with pockets to receive the vertical siding sheets, are nailed to the wall. These units, which should be considerably heavier in gage than the siding sheets, are installed before the siding is erected.

WALL FINISHES

Fig. 49 shows a method of flashing corrugated roofing against a wall at the top. Under a standard cap flashing a specially formed piece extends at least 6″ up the face of the wall, and an equal distance down over the corrugated roofing. Elastic cement or caulking compound is used to make the construction watertight.

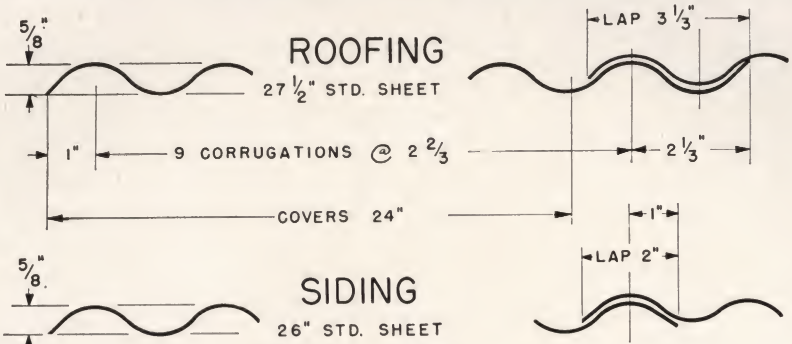


FIG. 45

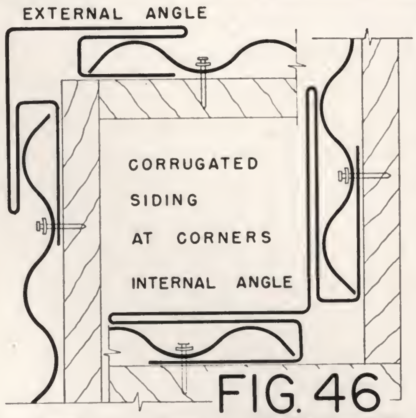
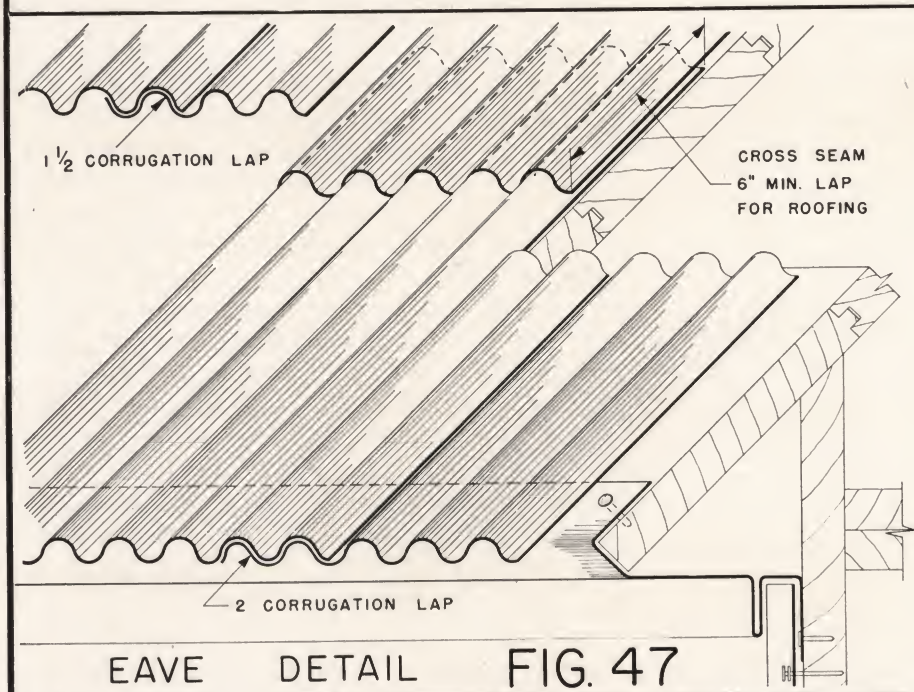
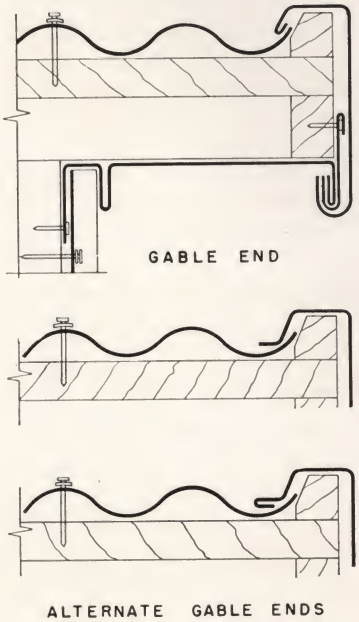
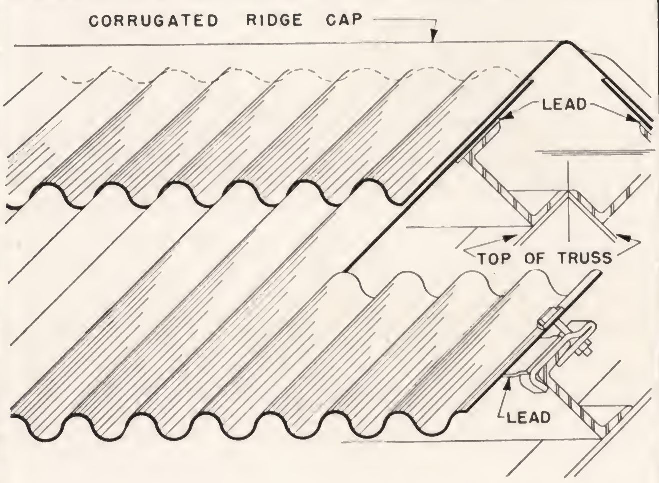


FIG. 46

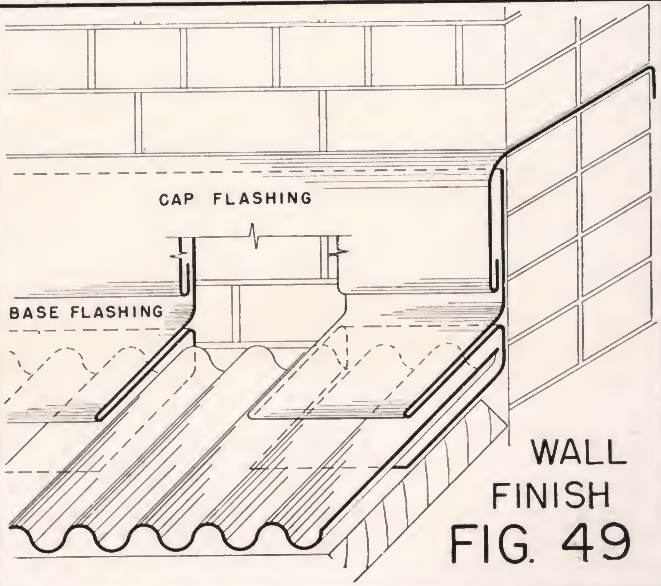




EAVE DETAIL FIG. 47



RIDGE DETAIL FIG. 48



WALL FINISH
FIG. 49

VERTICAL SURFACES AND COPPER WALLS

Metal sheets were being used to cover the walls and other vertical surfaces of buildings in increasing degree during the decade before World War II. A movement was under way, notably in Europe, for thin, light-weight exterior shells, because, with steel skeleton and reinforced concrete construction, walls need only be "curtains" to keep out the elements. Designers, accordingly, turned to metal, and found that by using copper sheets with proper insulation, they could build a wall only 4″ thick with the same insulating qualities as a masonry wall 20 times as thick. Such construction means great savings in space and weight. Moreover, the adaptability of metal to factory fabrication presents great possibilities for further economies.

The development of metal walls for buildings is still very new and, largely because of the forced abandonment of research and experiment from 1940 to 1945, nothing approaching standardization of construction methods has been reached. This Association makes every effort to keep informed on all new developments in this field and will be glad to furnish its latest information at any time.

COPPER SHEETS FOR WALL SHEATHING

Corrugated, crimped, or flat sheets are used for sheathing vertical surfaces. Corrugated copper and its use for siding is discussed on page 52. This construction is practical for factories, sheds, and other industrial units.

Crimped copper is used for sheathing the sides of penthouses, bulkheads, and similar enclosures. It usually is applied with flat-lock seams. As described on page 30, it is well suited for vertical surfaces as the crimps provide for expansion and contraction in the direction perpendicular to them, and the formation of locks with crimped sheets is not difficult on plane surfaces. Crimped copper nearly always is used in 16-oz. weight for sheathing, in lengths not exceeding 48″ long by 24″ wide. The sheets are *not* nailed, but are hooked together with loose-locked flat seams. A strip for engaging cleats nailed to the frame is soldered on each sheet 6″ from the top. Cross seams on vertical areas are unsoldered.

The methods of applying flat copper sheets on vertical walls are the same as those for flat and standing seam roofing. An example of the use of standing seam sheathing is given in **Fig. 36, Plate V.** The standing seams are folded down flat at the top and bottom to permit finishing and flashing. The flat-lock cross seams are left unsoldered for free movement. Sheets can be applied with flat seams in the same manner as in roofing, and for small surfaces this is good construction. For extensive walls, however, the standing seam method is less expensive.

COPPER SPANDRELS

Because of its light weight, workability, and pleasing color, and because it does not require protection and upkeep, copper is an ideal metal for spandrels. It is used in cast-alloy form, or as stamped or formed sheets. There are many methods of manufacture and construction, but no standardization of production or installation, as installations vary in size and in weight of metal used. There also is a lack of uniformity in the method of framing and connecting unit parts, as well as in securing them in place.

Cast spandrel units, which generally are heavy, are secured with angles fastened to the back of the spandrel and extending 3″ or 4″ into the masonry on each side. Spandrels also may be bolted to structural steel.

Sheet-formed units show many variations. Frequently they consist of large panels made with 1¼″ or larger corrugations as described on page 52. They are fastened to wooden battens with nails, screws, or cleats. Sometimes they are bolted to wood or metal brackets set into the masonry during construction.

Stamped sheet-copper units, which are comparatively new, are framed and braced in several ways, and in most cases are equipped with hooks or anchor bolts for securing them in place.

In general heavy gage sheets (20 or 24-oz.) are used. If they are to be stamped or formed soft copper is used; but plane surfaces should be cold-rolled.

This Association will be glad to advise with architects and sheet-metal contractors on any specific problems relating to spandrels which may arise.

DOMES, CUPOLAS, SPIRES AND TOWERS

Special forms of roofing such as domes, cupolas, spires, and towers, are designed to fit special conditions, but the principles of sheet-copper application apply in every case.

The many possible forms of these structural embellishments are covered with copper, because durability is very important where expensive scaffolding is necessary for repairs. Standard methods of sheet-copper application apply for covering them, the decision as to which to use depending on architectural considerations and the special features of the design.

For instance, on a small dome the batten method probably would not be appropriate or easy to apply because of the sharpness of the curvature, but the flat-seam method can be used, because the sheets are of such small size they can be shaped to and formed over the curved surface. For example, it would be practical to use 16″ x 18″ rectangular sheets on a dome with a radius as small as 12′, but smaller trapezoidal sheets would be needed for a small cupola.

In using the batten seam method on domes, the batten spacing is worked out so all bays will be identical, and the battens are tapered top to bottom, and saw-notched for bending to the roof curvature. The batten caps are made in short lengths with vertical sides crimped to permit bending. They are held down by heavy copper or brass clamps about 18″ apart, which are fastened by heavy brass screws through slotted holes.

While vertical seams in flat-seam roofing are sometimes soldered, most roofers prefer to use white lead, or mastic, to fill both these and the horizontal seams, because unsoldered seams look better and permit movement. It must be noted, however, that domes and spires are exposed to severe winds, and it is therefore of prime importance that all seams be full and tight.

All wood surfaces, battens and structural parts of domes and spires should be impregnated to make them fire and weatherproof. It is good practice to use heavier than ordinary members because of wind pressures.

On monumental buildings it is not uncommon to have battens and similar ornamental pieces made of heavy copper, or copper-alloy, to fit the curved or steep slopes.

A single pattern is used for cutting the sheets of all the bays. These patterns usually are made of roofing paper or galvanized iron with proper allowance for seams. Cross seams may be staggered, and if this is decided on it is advisable to lay out two sets of patterns for alternate bays. Where curved or double-curved surfaces are to be covered, the size of the sheets is limited to areas that depart only slightly from a flat surface. On very sharp curvatures it is difficult to form the battens, and to keep longitudinal seams from binding, so it is better to use flat-seam construction.

In laying standing seam roofing, the considerations are much the same. The correct spacing of longitudinal seams is important in eliminating waste and permitting the use of single patterns for adjacent or alternate bays. Here, too, the cross seams may be staggered. On curved surfaces short sheets, cut trapezoidal, are used. Sharp curves cause excessive stretching or crimping and render the standing seam method impractical. Accurate patterns must be made, with proper allowance for seams.

Flat-seam roofing is applicable to virtually all styles of domes and towers. As in flat roofing work, it is best to use small sheets. On domes the sheets usually vary in size from one course to the next, but those in any one course generally are made from the same pattern. If they are laid in horizontal rings, the vertical joints are staggered. Sheets also may be laid with diagonal seams, if that effect is more desirable.

Example of a modern copper roof is this installation on the Hanson Place Central Methodist Church in Brooklyn, N. Y. Completed in 1930, this roof has provided entirely satisfactory service. It is batten seam construction of 16-ounce sheet copper, which has been lead-coated. In 18 years not a cent has been spent for upkeep.

SECTION III—FLASHINGS, GUTTERS AND OUTLETS

Roofs and walls of buildings have many weak points that must be safeguarded against leaks. In the main these occur at the joints between the plane surfaces, vertical, horizontal and sloping, that form the exterior of a structure. Obviously, all must be watertight. Sheet-metal flashings, and particularly those of copper, are universally accepted as best for this purpose.

Roof intersections, ridges, hips and valleys, gutters, and wherever parts of a building project above or through the roof, as walls, parapets, chimneys, dormers, vents, etc., are all places of possible trouble from leaks.

The sole purpose of the whole roofing, flashing and drainage system is to shed water and carry it away from the building quickly and efficiently. *Valleys and gutters are not basins or reservoirs, but channels to lead water away*. Wall flashings must be placed to turn all water and moisture to the outside face, where additional means of rapid drainage are provided.

Leaks in metal flashings may be due to corrosion or to mechanical failure resulting from bad design or improper installation, or both. The general acceptance of copper by the architectural profession and building industry as the best metal for flashings is due to its long life, ease of application, and minimum maintenance costs.

But no matter how good a material may be, if it is misused it cannot perform satisfactorily. Copper, as well as all other materials, must be used properly if it is to give the traditionally fine service that is expected of it.

FLASHINGS FOR ROOFING TILE

Roof tile is made of terra cotta and of concrete in a variety of designs. Terra-cotta tile has been used for centuries in the warm Mediterranean countries. Concrete roof tiles have been put on the market more recently.

Due to the design of the tiles, roofs covered with them require special treatment at flashing points. The flashings generally are made of larger sheets than those used with other roofing because of the need of covering joints near the flashing points, and of conforming to the irregularity of the construction.

The use of heavy copper, not less than 20-oz., is recommended for roof tile flashings, for its greater thickness better withstands the malleting and drawing incident to dressing the metal over the tile.

Good rules to follow when designing flashings for roof tile are:

(1) Use enough copper to cover all undulations at all flashing points;

(2) Apply the copper loosely, so that the heavy tile will not stretch or tear it;

(3) Fasten as little as possible; let sheets be held in place by the weight of the tile.

FLASHINGS FOR STONE WORK

If copper is applied directly to light-colored building stone or marble, sweating or condensation on the under side, because of temperature differences when copper and stone are in direct contact, may cause discoloration. To avoid this, waterproof paper or felt should be laid under the copper.

With some light-colored stones, such as marble or limestone, lead-coated copper works out admirably for flashings and the possibility of run-off stain is avoided. This material is discussed on page 29.

Design should always be such that the wash from the metal does not flow over the face of the stonework. This can be overcome by draining the stonework inward, except for the small portion beyond the outside reglet. If this method is not expedient the copper can be turned down over the face about 1½″, hemmed ½″, and flared out about 30° to form a drip about 1″ wide.

Good practice in stonework, with parapet and other walls faced with stone, calls for reglets rather than for step flashings in the joints. The reglet is cut straight or at an angle across the stone as occasion may dictate.

Many experienced stone setters consider copper or lead wedges and lime mortar the best method of filling reglets. The objection is the necessity for frequent repointing. Lead wool (or molten lead) does away with this maintenance expense. Page 94 and **Plate XXVII** contain data and details on reglets and caulking.

FLASHINGS FOR TERRA COTTA

Although architectural terra cotta does not have today the wide use as an exterior facing for buildings it enjoyed twenty-five years ago, it still has a definite, if limited, place in building design.

Because terra cotta is susceptible to frost action there is one principle that controls its use, viz.: there must be as complete a cutoff as possible so that moisture cannot penetrate far enough into open joints and crevices to freeze and spall the blocks. This means the use of metal flashings to form an integrated dampproofing seal.

Built-in flashings, furnished and installed by the sheet-metal contractor, are made to measurements furnished by the mason, who, if he is experienced, generally wants a more comprehensive cutoff than is shown on the plans.

Sheet-metal contractors will do well to cooperate with the mason in installing flashings that do a thorough job of keeping water out, for when failures occur, workmanship rather than material is usually blamed, and the sheet-metal man will find himself in an awkward situation if his contract contains one of those avoidance clauses in which responsibility for materials and workmanship is shifted from the architect to the contractor.

FLASHING AND GUTTER DETAILS

The plates that follow illustrate, and the text that accompanies them (on facing pages) describes, recommended methods of using copper sheet for flashings and gutters. As drawings and text are complementary, omissions from the one of details that appear in the other may be due to inadvertance, but more probably occur because of space limitations and the desirability of avoiding reiteration. The reader and student will also note that, although every effort has been made to so do, details in a drawing that have been described in a preceding plate, are not always back-referenced. Therefore he will do well to consult the Index and to study the preceding plates, whenever he encounters something in the drawings that is not mentioned in the accompanying text.

RIDGES AND HIPS

Fig. 50 shows four types of hip or ridge flashings. In general, such pieces are made from cold-rolled strip in 8′ lengths, and laid with unsoldered 3″ lap joints as indicated. The methods are interchangeable. For instance, the copper (copper-alloy) clamps shown in Detail **2** can be used with any of the other methods.

A low ridge flashing without a projecting roll is made as in Detail **1**. The ridge boards covering the shingles are secured to the roof by nailing to blocks placed at intervals on the sheathing (the shingles being cut to fit around), or on a continuous block formed of 7/8″ strips. The flashing piece is secured to the edge of the ridge boards by nails, as shown, or by brass wood screws. It has a slight projection (about 1″), bent down to the shingles after nailing, to shed water and cover the holes.

The method in Detail **2** requires a specially shaped ridge piece to take the flashing roll. The roll is secured by screws in the sides as shown, and the apron, if more than 6″ wide, should be stiffened against wind by 3/16″ x 1″ copper (copper-alloy) clamps or straps, 3 to each length. These straps are secured by brass screws through countersunk holes, oversized (about 1/16″) to permit longitudinal movement.

The method shown in Detail **3** requires no special ridge board, and is an excellent way of securing a large ridge roll. The board keeps the metal in place and is set so the roll can be fastened to it by screws, making it unnecessary to drill the shingles or slates.

Detail **4** shows a simple method of finishing a ridge with a stock ridge roll. These are made of cold-rolled copper with rolls up to 3″ diameter and 3½″ aprons. They are fastened with brass screws set through lead washers into holes drilled in the shingles or located above their upper edges. They require no ridge board. Good practice calls for screws and washers, with over-sized holes to allow for movement, covered with copper caps.

Fig. 51 shows how the intersection of shingled (or slated) hips is flashed by means of a wood batten, a copper batten cover, and small pieces of copper sheet woven into the shingle courses as they are laid. Each of these small pieces laps the one beneath it about 3″, turns up against the batten side, and is fastened to it by nails, or brass screws as shown in the sections.

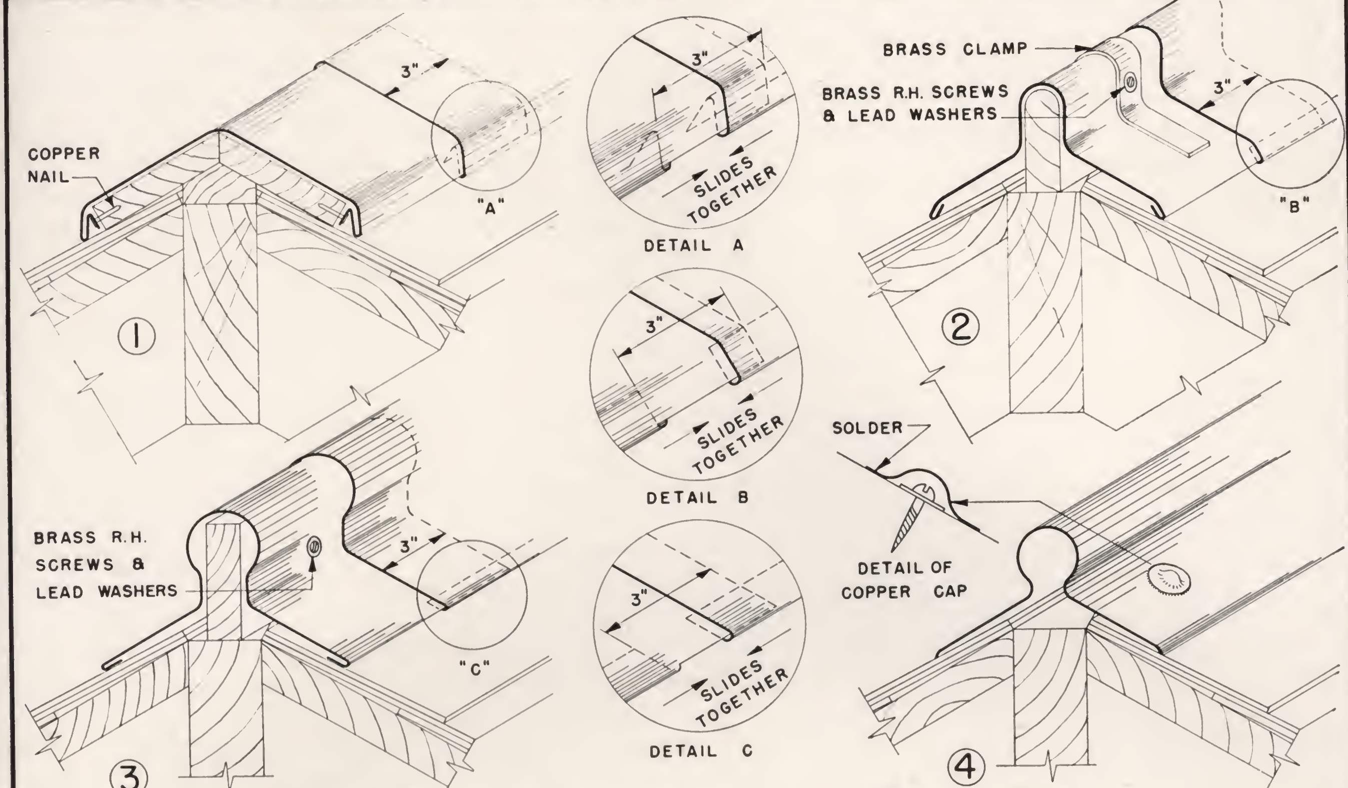
Section **A-A** shows the hip flashing in two pieces locked together just as for batten roofing **(Fig. 26, Plate I)**, and held by brass screws let into the batten sides. Section **B-B** shows a spring-type, one-piece flashing that is secured by heavy copper (copper-alloy) clamps, as **Fig. 50** Detail **2**.

Fig. 52 shows how the hip or ridge of a shingled roof is made watertight with concealed metal flashing pieces. The roof is covered as usual up to the wood nailing strip running along the ridge or hip. As the shingles covering the hip are laid, copper flashings, cut with tabs as shown in the detail, are placed between each course so as to cover the nail heads. These metal pieces are cut to extend almost to the butts of the shingles covering them, which means that with a shingle lap of 3″ the flashings will lap each other almost 3″. They are held in place by folding the tabs over the top edges of the shingles upon which they rest.

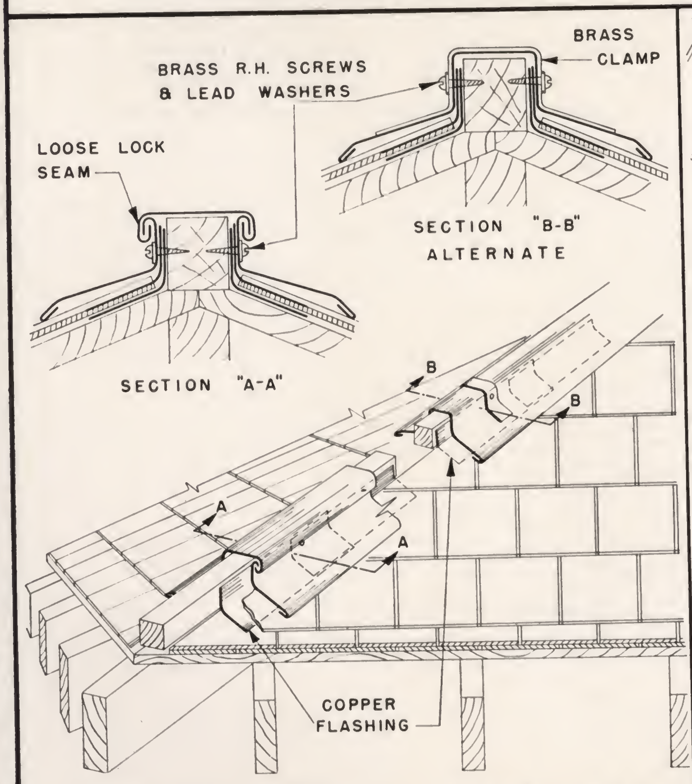
LONGITUDINAL MOVEMENT

Where the length of any flashing—cap, base, through, cavity-wall, spandrel, ridge, hip,—is fairly short, say 30 feet or under, the type of connecting joint between the sheets or strips forming it is immaterial so long as it is watertight. According to conditions of slope and drainage it can be lapped, locked or soldered. But continuous runs of more than 30 feet must be broken up by some type of loose-locked joint, filled with elastic cement or white lead, that will permit the metal to move.

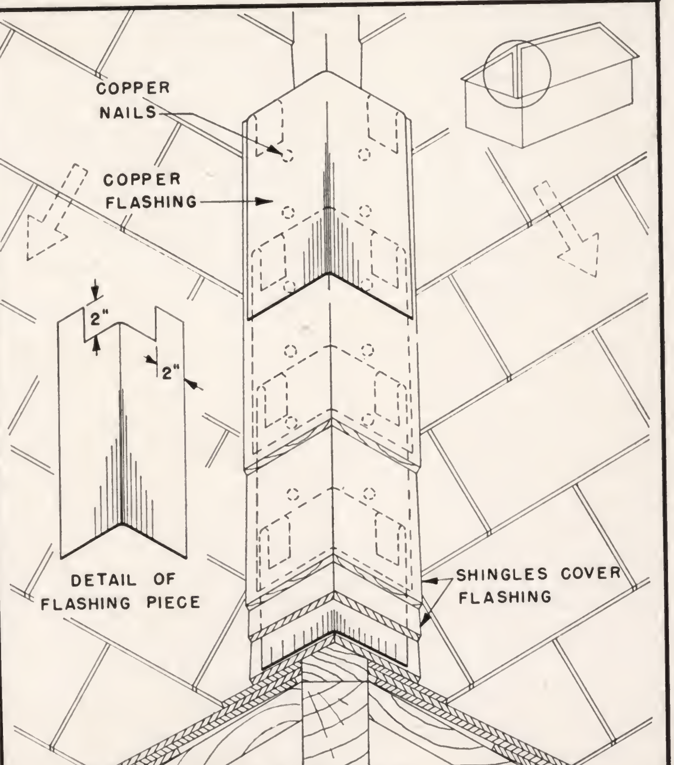
This installation detail is not shown on the drawings, and may not be specifically mentioned in the text describing them, but *it is a rule that applies to all continuous flashings shown in this book.* To be safe specify expansion joints every 24 or 30 feet, the coverage of 3 lengths of copper sheet. Under extreme conditions, in latitude 42, thermal movement can be as much as 3/8″ in 30 ft. (See also page 15, and Section 46, Specifications, on page 131.)



HIP OR RIDGE FLASHINGS FIG. 50



HIP FLASHING FIG. 51



SADDLE HIP OR RIDGE FLASHING FIG. 52

DECK AND VALLEY FLASHINGS

Fig. 53 presents two ways of flashing a tile roof that joins a flat deck covered by copper roofing. The method on the left is used when the tile finishes below the deck and the roofing laps over the edge of the tile. A tile deck mould is secured to the roof sheathing just above a special piece called "top-fixture." The flashing is turned down over the deck mould far enough to cover the nail holes in the tiles, and is hooked over a cleat or edge strip. The **"Alternate"** method shows a ¾″ edge strip formed from two folds of copper. The roof edge of the flashing is locked into a soldered flat seam securely held to the roof sheathing by cleats.

The method on the right shows the flashing when the tile ends above the roof instead of below. The deck sheets are carried up on a cant strip to the top of a ridge board, where they are lapped by another piece carried out on the tile top fixture about 4″. The tile ridge roll then is placed over the flashing, the weight of the roll holding it in place. This flashing may also be joined to the roofing of the deck by soldered lock seams, instead of the open lap shown.

OPEN VALLEYS

Fig. 54 shows an open valley flashing where the intersecting roof planes have the same slope. The valley sheets are 16-oz. copper 96″ long. While the cross seams usually are locked and soldered, a better installation, where the slope is steep and the flow is unobstructed, is to lap the sheets and leave them unsoldered. This takes care of expansion and contraction. In such construction the sheets have a head lap (vertical distance between bottom edge of upper sheet and top edge of lower) of at least 3″. Side edges of the flashing are folded back onto the sheets to form ½″ locks for cleating. The valley is secured with 2″ cleats, 12″ on centers.

Slates or shingles are laid so the exposed portion of the valley is not less than 4″ wide at top, and increases in width 1″ in 8′ toward the gutter. This taper minimizes trouble from ice and snow.

The flashing extends up under the roof covering not less than 4″. The metal must not be pierced by nails fastening slates or shingles.

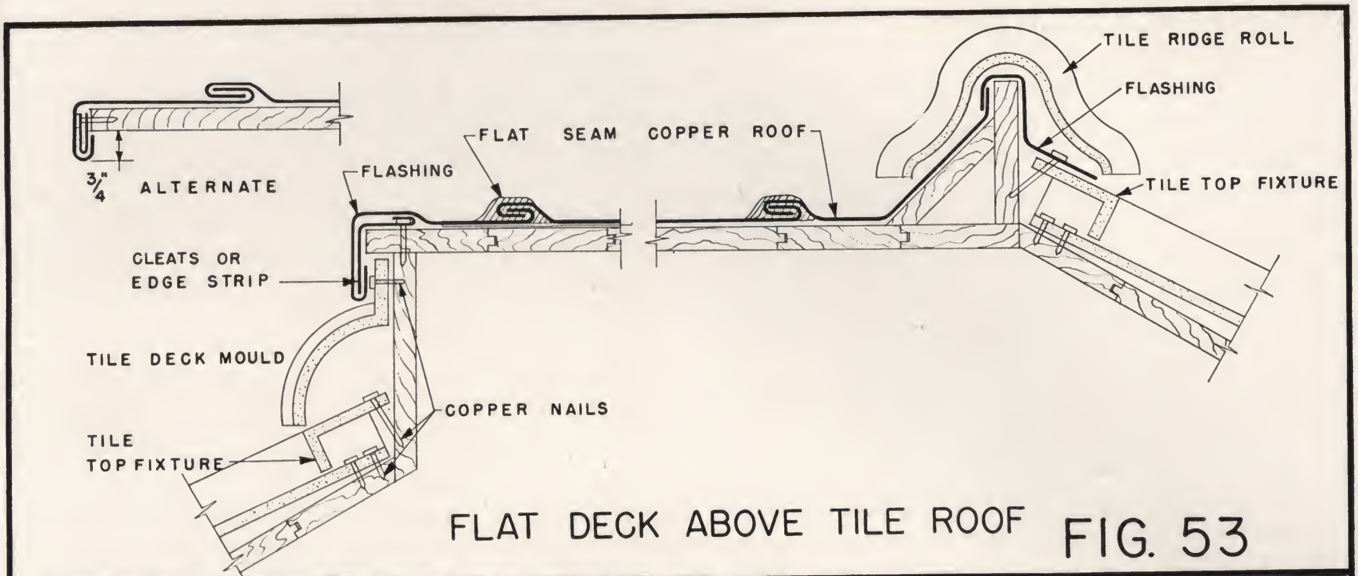
A wood slat, or cant strip, about ⅛″ x 1″, is nailed to the roof far enough back to raise the butts of the slates or shingles about ½″ above the metal, thereby reducing the possibility of "line corrosion," where shingle, metal, and air come together. This "line corrosion" sometimes occurs in localities where the contents of the atmosphere make corrosive solutions of the moisture held by capillary attraction at the metal-shingle-air line. Raising the butts prevents moisture being held in contact with the metal. The cant strip is set at a slight angle and has weep holes or slots at low points to drain out any condensate running down the roof under the shingles. Further details of this important feature of valley installation are set out in **Figs. 58, Plate XII,** and **85, Plate XXIII.**

The **"Alternate"** shows a cant strip made of copper and soldered to the valley sheet. It is laid parallel to the valley edge of the shingles, as any condensate will run over it and weep holes are not necessary.

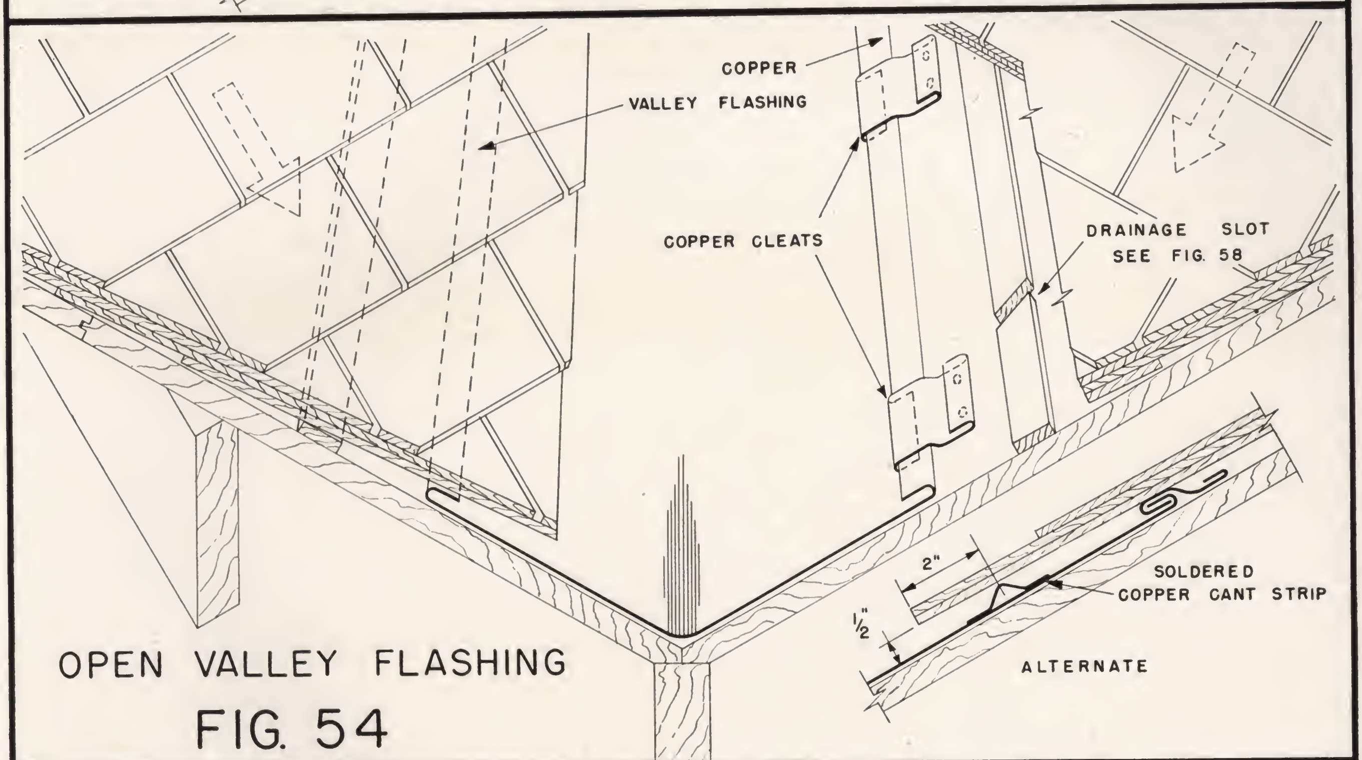
Fig. 55.—When two roof slopes deliver unequal amounts of water to a valley, the larger may force the smaller amount back on itself and up beyond the top of the flashing. To prevent this a 1½″ crimp is formed in the copper at the bottom of the valley, as shown, to break the force of the water.

Fig. 56 shows an angle, or tee, as an alternate for the crimp in **Fig. 55.** It is formed of copper, and soldered to the valley sheet on the slope opposite the one which delivers the larger quantity of water.

(See also Note on Page 58.)

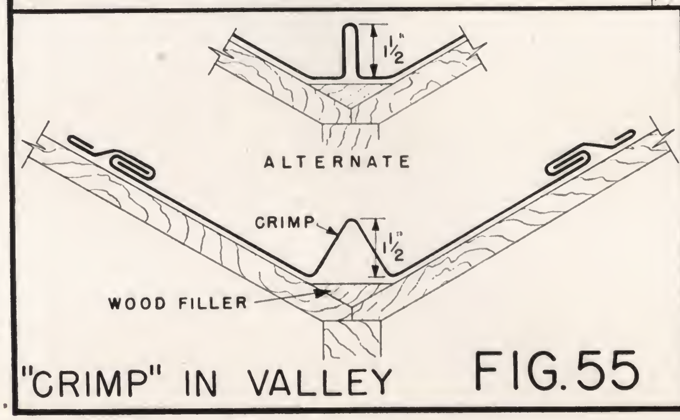


FLAT DECK ABOVE TILE ROOF FIG. 53

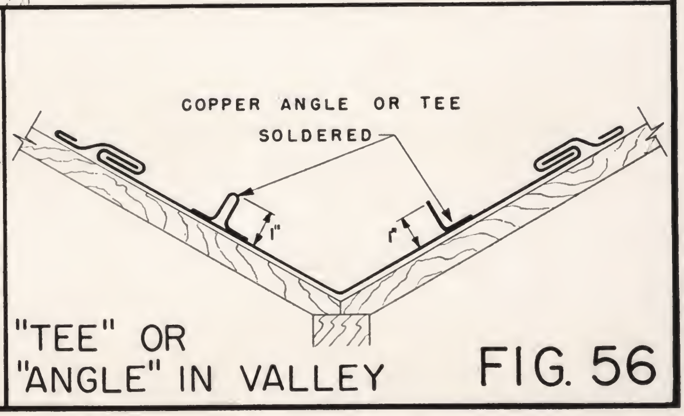


OPEN VALLEY FLASHING

FIG. 54



"CRIMP" IN VALLEY FIG. 55



"TEE" OR "ANGLE" IN VALLEY FIG. 56

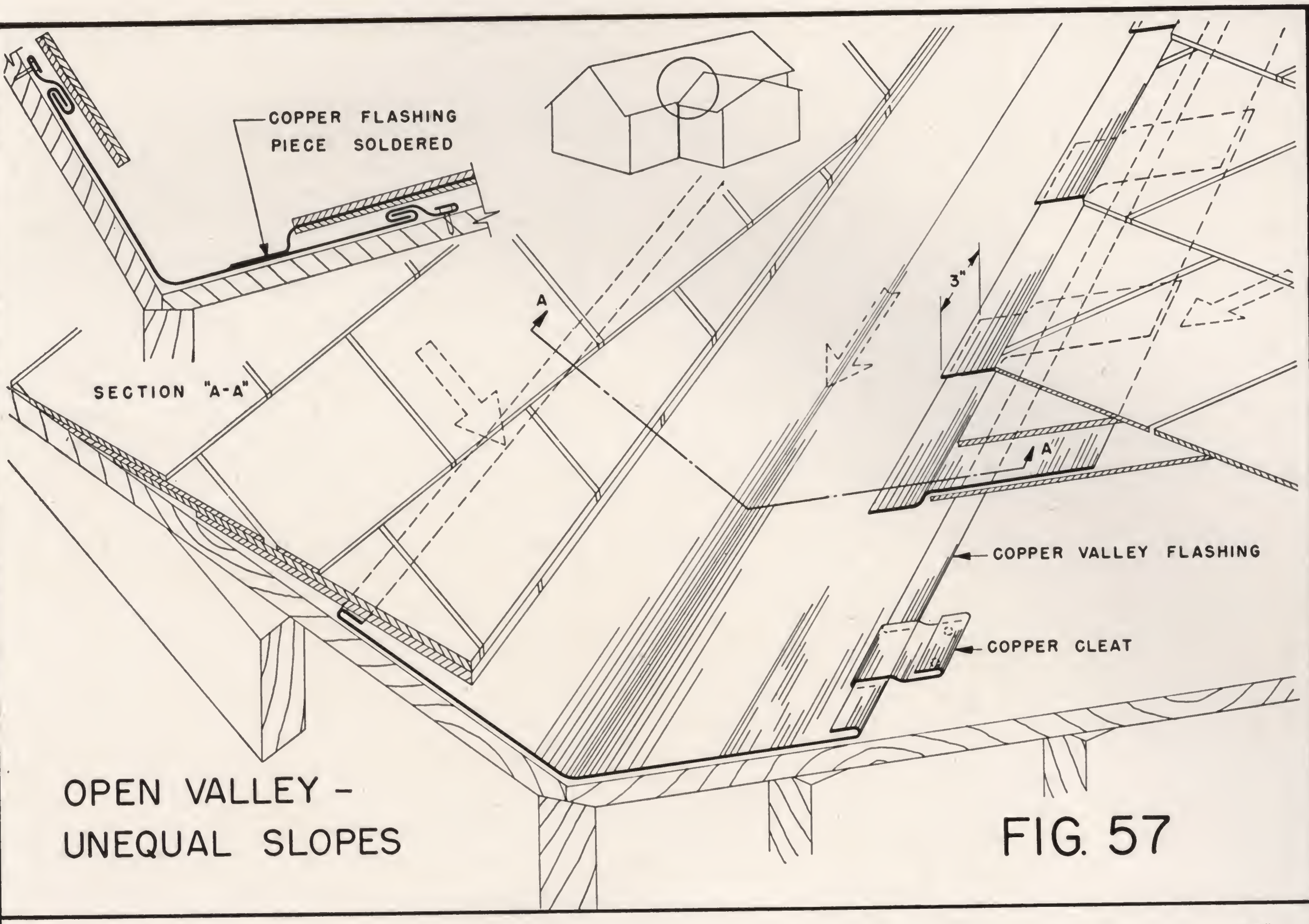
OPEN VALLEYS (Continued)

Fig. 57 shows recommended construction in those cases where water from a large, steep surface discharges into a valley formed with a surface that is much flatter. Copper flashing pieces are inserted between each pair of shingles next to the valley on the flat slope, each piece lapping the next lower one 3″. The pieces are cut and formed as shown in Section **A-A,** and are soldered to the valley flashing. This construction, obviously, is more expensive than those illustrated in **Figs. 54, 55** and **56** but it gives greater safety where one slope is so much steeper than the other that in a downpour water would wash over a crimp or soldered cut-off. Disadvantages are that it is difficult to make a neat job, and that there is the possibility of "line corrosion" in localities where the atmosphere has a high acid content.

Fig. 58.—If a valley is formed by two parallel roof slopes, that is, with ridges parallel so that the shingles meet the valley perpendicularly from both sides, the valley is actually a gutter with practically no slope, and special construction is necessary. The shingle butts are kept off the valley sheets by means of a metal cant strip soldered to the valley sheet. If a wooden strip is used, as in the **"Alternate",** it is held by copper straps 2″ wide folded over the batten, their ends being soldered to the valley. Cant strips are placed from 1″ to 2″ back of the shingle butts, slightly angled, and made with ¼″ holes or slots, to allow drainage for possible moisture. (See **Fig. 85 Plate XXIII.)** The strips must be high enough to allow the shingles, or slates, to clear the valley sheet ½″ so as to do away with "line corrosion." The flashing is carried up the sides under the second course of shingles, and fastened with cleats. In the illustration the wide gutter trough calls for soldered flat-seam construction.

NOTE

Both drawings on **Plate XII** are of valley constructions that are rarely met with in ordinary architectural and sheet-metal practice. However, their very infrequency serves to emphasize the importance of a thorough understanding of what are recommended methods of installing valley flashings. For valleys are a frequent source of leaks, and in almost every case investigated design and construction, rather than materials, have been at fault.



OPEN VALLEY -
UNEQUAL SLOPES

FIG. 57

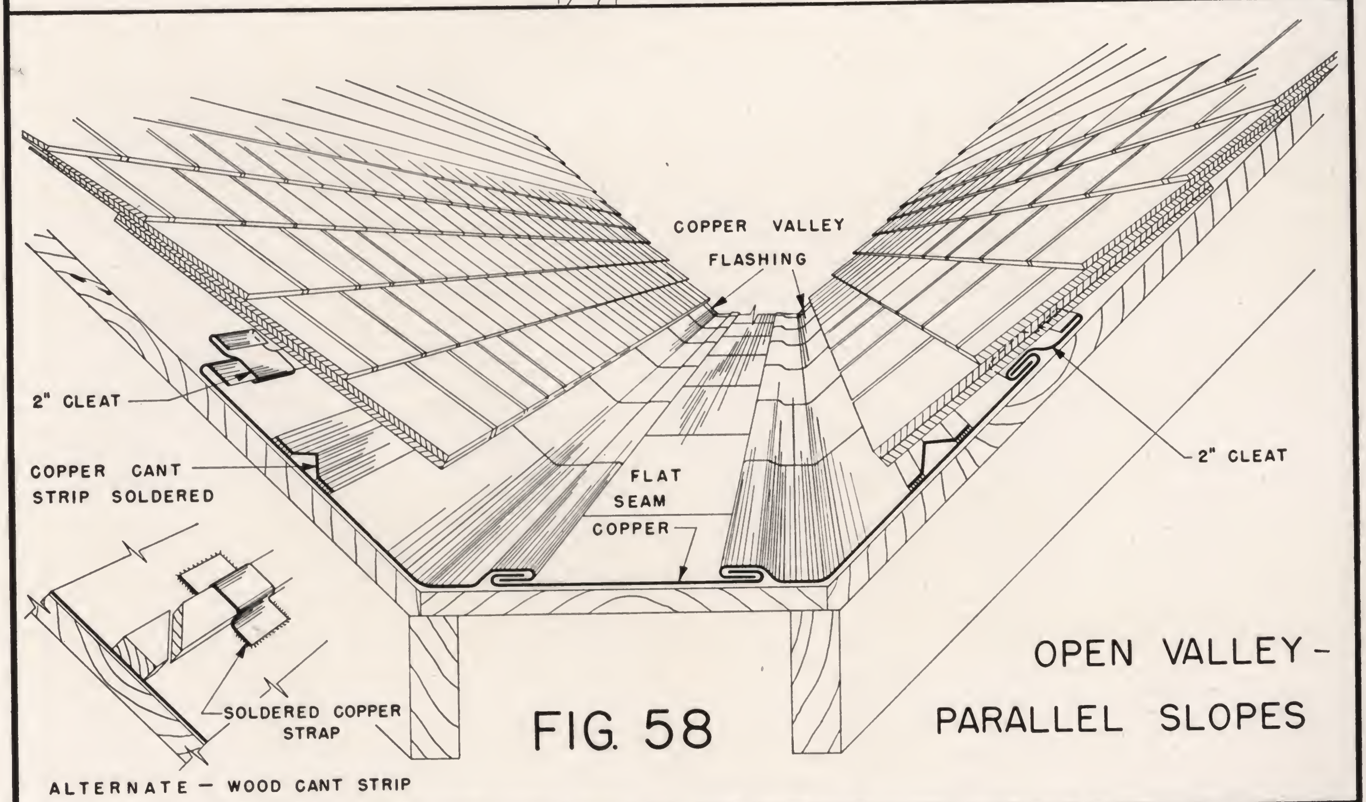


FIG. 58

OPEN VALLEY -
PARALLEL SLOPES

CLOSED VALLEYS

Closed valleys find their proper place on the slate roofs of fine buildings where the architectural treatment calls for soft roof lines and closed plane intersections. Here the concealed flashings illustrated in **Fig. 59** are used.

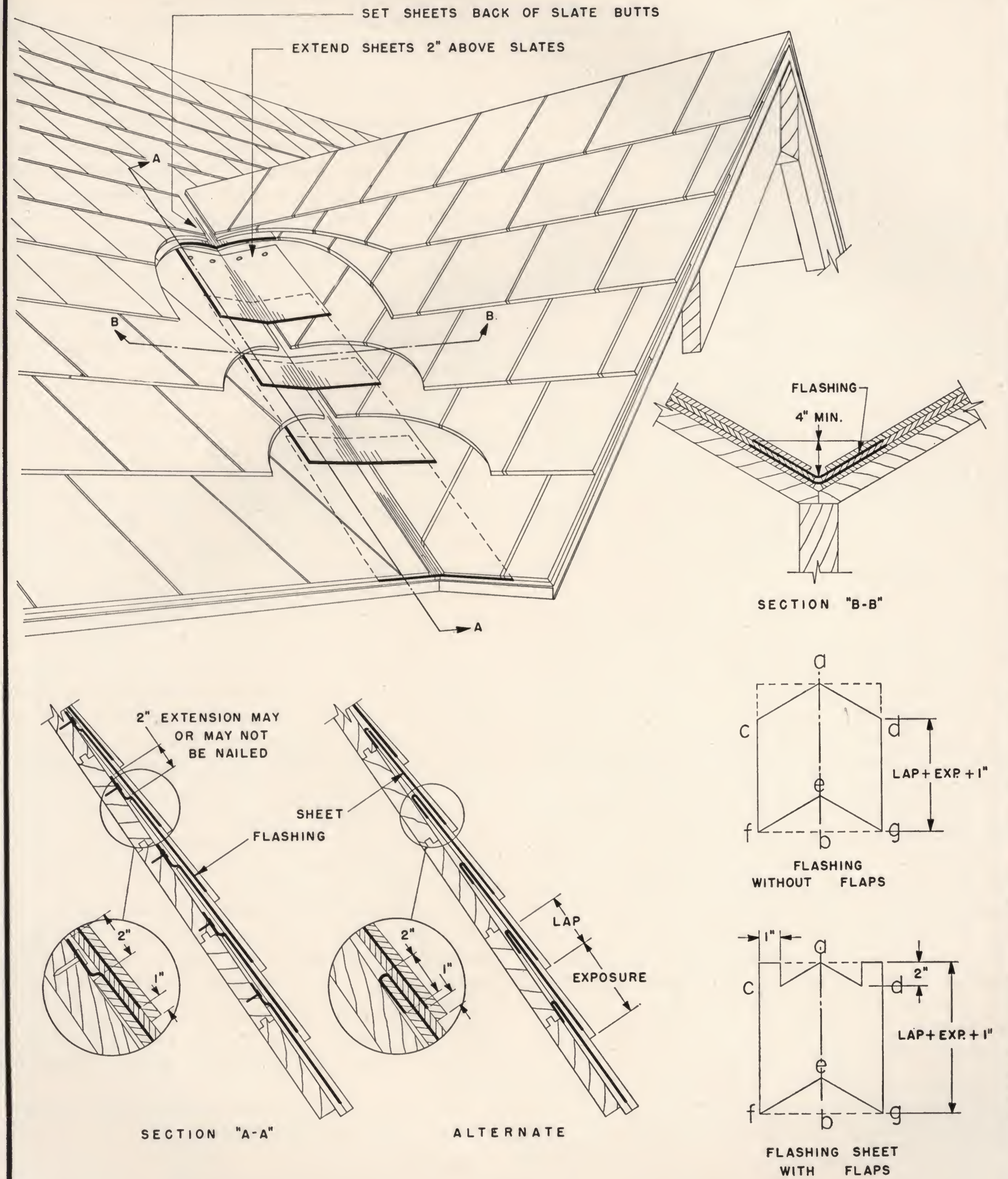
They are not recommended for slopes of less than 2 on 3, for the snow held in valleys by the rough slates melts and freezes during thaws so that water backs up over and runs down behind the single flashing pieces.

This construction calls for a series of separate copper sheets not lighter than 20-oz. inserted between every course of slate. The sheets are made from large sheets or rolls, as shown in the diagram at lower right, by cutting along the parallel lines ***ac*** and **ef,** and ***ad*** and **eg.** The cut sheets are folded along the line ***ae*** to fit the valley. This is all done in the shop, and all sheets for the same valley are formed from a templet made on the job.

The flashing sheets should lap the shingles below at least 3″, and should be carried down just short of the butts of the course above, as shown in Section **A-A** and its **"Alternate".** Their width should be sufficient to assure a valley with a minimum depth of 4″, as in Section **B-B.**

It is not necessary to nail these flashing pieces as they are firmly held by the slates over them. However, if nailing is deemed advisable, the pieces are made with an extra 2″ of length (Section **A-A**). A better way to secure them is by the flaps shown in the **"Alternate"** to section **A-A.**

Closed valleys are also used with wood shingles. The installation methods are the same as for slate.



CLOSED VALLEY FLASHING

FIG. 59

CHANGES OF SLOPE

Fig. 60 shows methods of flashing the break at changes of slope in shingle or slate roofs. The copper extends under the shingles of the upper slope as far as possible without being punctured by nailing, and is cleated. On the lower slope the flashing extends out 4″ on top of the shingles to cover the nail holes. A cant strip is used to raise the butts of the last course of shingles on the upper slope to permit proper laying. The strip is placed over the flashing and held with soldered straps as in **Fig. 58, Plate XII**. The exposed end of the flashing is turned back to stiffen it and hold it against the shingles. Where exposed to severe winds the flashing is screwed down with brass R. H. screws set through washers.

Fig. 61.—If a closed and mitred joint is desired with shingles, a concealed flashing is used. On the upper slope the sheet lies under the last course and is held with cleats. On the lower slope it is carried down between the shingles of the top double course to within ½″ of the butt of the top shingle. This course of shingles is fastened with brass wood screws passing through lead washers inserted immediately on top of the flashing between the two courses. The washers prevent leakage through the holes in the shingles or slates. A cant strip is provided on the upper slope as in **Fig. 60**.

Fig. 62 shows the flashing of a flat copper deck discharging onto a sloping shingle roof. The flashing laps the shingles 4″ and joins the copper roofing by a soldered flat-lock seam turned in the direction of the flow. Generally, the metal is stiff enough, with its turned edges, to hold to the shingle, but if there is likelihood of the lower portion being lifted by wind it is secured with brass R. H. screws set through lead washers as in Section **A-A**.

A detail that requires no solder appears in **Alternate Copper Deck**. The flashing is continuous along the edge.

Two examples of edge flashing for a deck covered with built-up or compo roofing are shown in the **Alternates for Compo Roof** at the right of **Fig. 62.** In each the lower edge of the copper is turned back ½″ for stiffness. The flashing piece should lap the shingles at least 4″ and be held down by R. H. brass screws set through lead washers. The upper detail illustrates a two-piece flashing joined by an unsoldered lock seam that acts also as a gravel stop. In the lower the flashing is in one piece. It is brought up on the main roof and, after forming a crimp to retain the gravel, is extended out on the roofing 4″, covered with asphaltum paint, and is nailed, at about 8″ intervals near the inside edge, through the felt. The joint between metal and felt is made tight as described below.

If the vertical distance from shingles to top of crimp is more than 8″ it may be advisable to make the flashing in two pieces joined by a flat-lock seam secured by cleats to the vertical surface of the roof boards. Such a seam would be unsoldered and filled with white lead.

The copper extends out on the roof on top of the felt 4″, is nailed through the felt to the sheathing with copper (copper-alloy) nails, and then is covered with two additional layers of felt extending out on the roof. The metal also may be laid between the layers of felt instead of on top, but most roofers prefer the former method, as it prevents interruption of the roofing work.

The copper never should be laid directly on the roof boards with the felt on top of it, for the felt will pull away and leave an open joint at the junction.

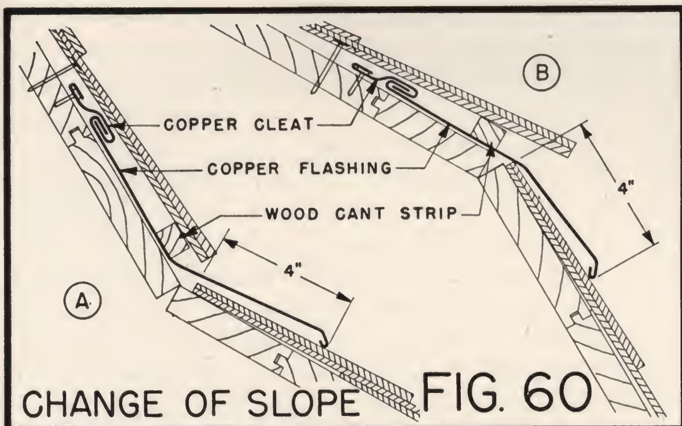
GABLE ENDS

Methods of finishing the gable ends of copper roofs are described under the respective types of roofing. Slate and shingle roofs frequently are left unflashed at the gables. Copper flashings sometimes are desirable, however, and they are placed as shown in **Fig. 63.** In Details **A** and **B** the flashing consists of long strips that lie 3″ on the roof and are hooked to different kinds of edge strips, one copper and one brass. In Detail **C** short pieces of metal are woven in with each course of shingles (or slate) somewhat as is done in **Figs. 57, Plate XII,** and **59, Plate XIII.** The flashings lap at least 3″, and since the pieces are short they can be fastened with copper nails. The top edges are folded at right angles to slip under the shingles. Such flashings dress the roof edge and give it a more solid appearance. They prevent water being blown under the shingles, and edge-lifting and straining by winds. Highly important, too, is the cutting off of infiltrating air currents that mean heat losses.

Roof edges are also important on built-up and composition roofs not enclosed by parapets or walls. Copper flashings along such exposed edges make the roofing watertight and prevent the layers from being separated and lifted by wind. Some distributors stock special strips for this purpose. They are generally in the form of angles, with or without a projecting fold to act as a drip at the corner.

Other types of edge finishes and gravel stops are illustrated in **Fig. 125, Plate XXXIV.**

(*See also Note on Page 58.*)



CHANGE OF SLOPE FIG. 60

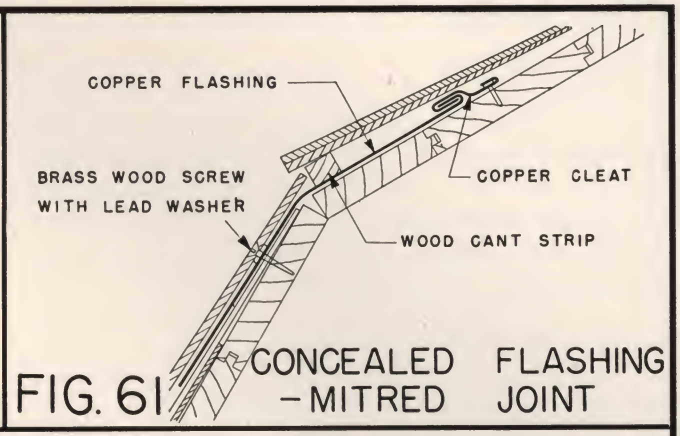


FIG. 61 CONCEALED FLASHING - MITRED JOINT

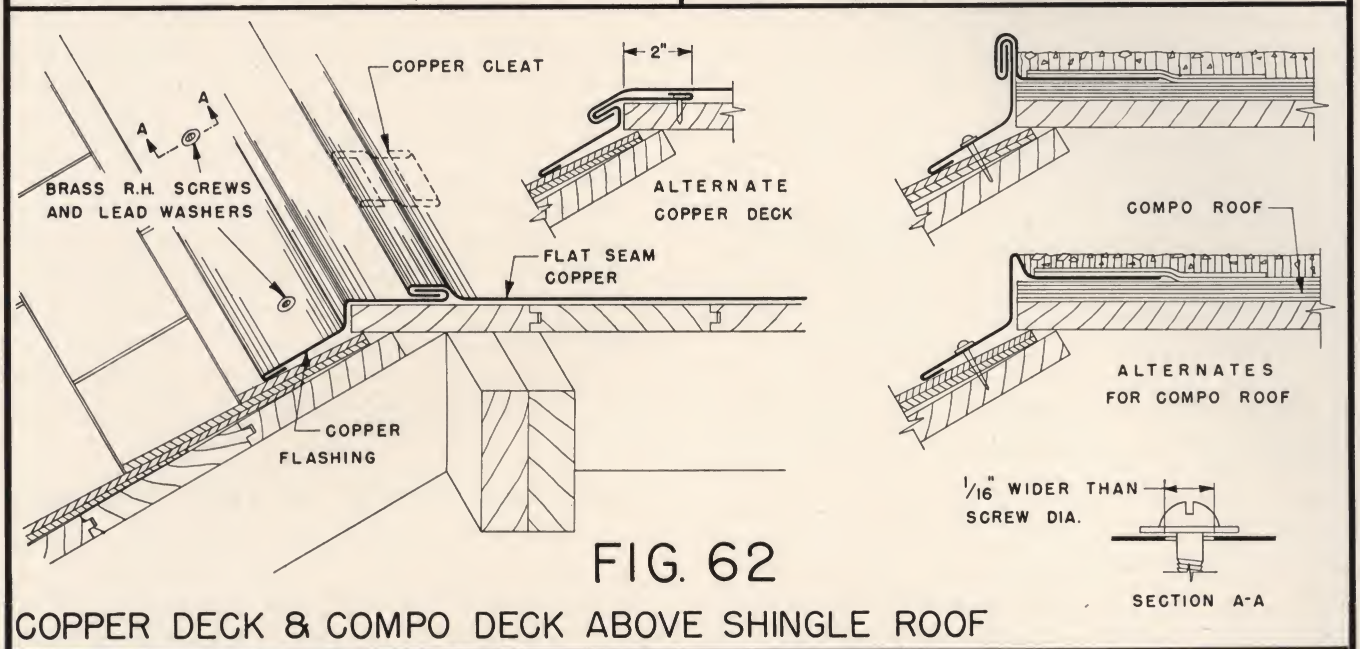
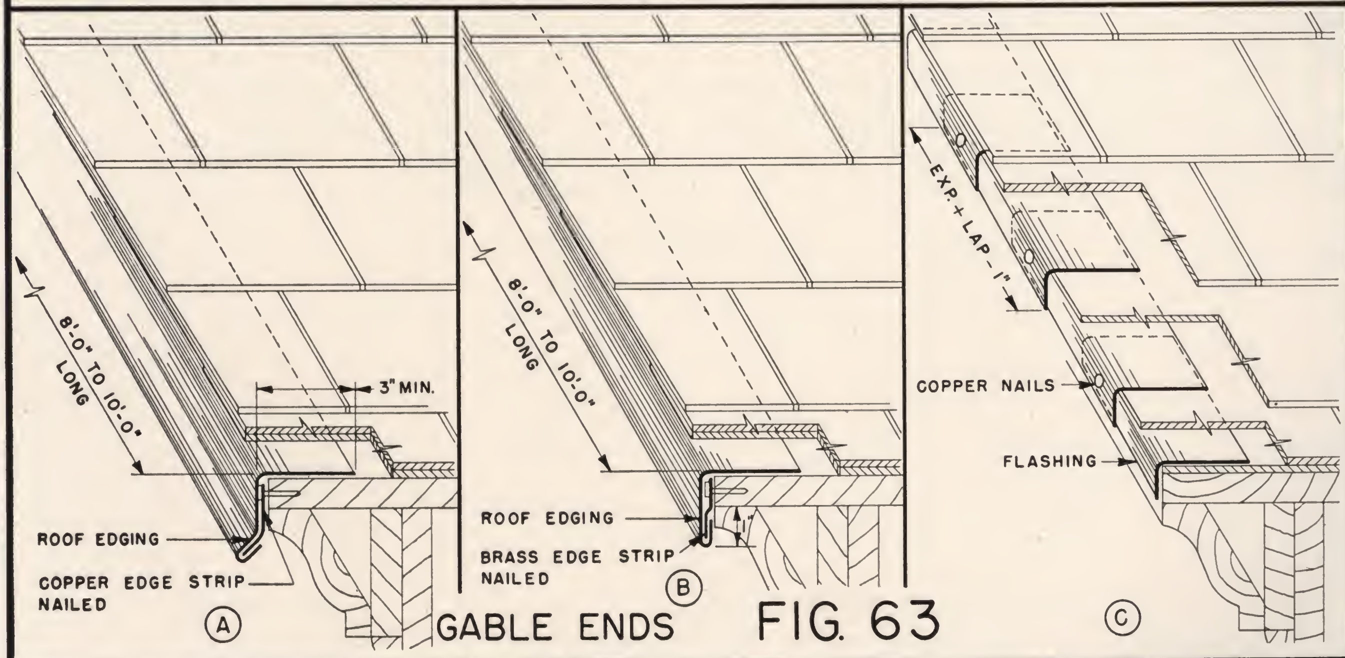


FIG. 62
COPPER DECK & COMPO DECK ABOVE SHINGLE ROOF



GABLE ENDS FIG. 63

WALL FINISHES

SHINGLE ROOFS

Fig. 64 presents a method of flashing a vertical wall when the wall runs along the side of a shingle or slate roof. This is an example of the familiar cap and base flashing. The base flashings, which are woven into the shingle courses, project on the roof 4″ and up the wall at least 6″ and preferably 8″. They are nailed to the sheathing, or can be hooked over the tops of the shingles, as in **Fig. 59, Plate XIII.** The cap flashings are inserted between the brick courses, lap the base flashings at least 4″, and lap each other at least 3″ at the sides. The base flashings, being carried down nearly to the butts of the shingles immediately above them, lap each other about 3″. Cap flashings are best built into the wall as the masonry is erected. If this cannot be done, they are secured as described below. Note the foldbacks at the bottom edges of the cap flashings for stiffness.

Where local wind action is prolonged and severe the exposed edges of the cap flashings can be carried into the vertical joints of the brickwork above the next step flashing and the caps soldered where they lap at the sides. This prevents water being driven under the edges.

Fig. 65 shows a concealed gutter made as part of a stepped flashing—a nice example of the coppersmith's craftmanship.

The gutter can be any necessary size (2″ x 2″ being large enough for most of the places where this construction is used), but the flashing must extend out on the roof not less than 3″. Concealed gutters of this kind find wide use in buildings of functional design where flat cantilevered canopies and roofs are commonly built over entrances and porches.

The flashing pieces are made in the shop from templates that fit the roof slope and step up with each brick course. The only soldering is at the top, horizontal joint between pieces; the exposed side pieces lap about 4″.

This kind of stepped flashing is not often used today, but it was common enough on churches, schools and even small dwellings when labor cost less. When done by a good craftsman, it presents a neat appearance and acts as a complete moisture cutoff.

Fig. 66 shows a way of flashing when a shingle roof abuts a brick wall, at the top of the roof. Each end of the cap flashing is turned back as shown, the built-in end to act as a dam, the lower for stiffness. The flashing is built into the brickwork and laps the base flashing 4″. The base flashing extends out on the shingles 4″ to cover the nails, and before being placed the outer edge is turned back on itself ½″ to form a dam. The base flashing is held by 20-oz. cleats 12″ apart secured to the brickwork by copper-alloy nails driven into the joints. To complete the job the cap flashing then is turned down over the base flashing in the usual way. If the roof slope is so steep that the flashing need be carried up the masonry but 2″, it can be made in one piece.

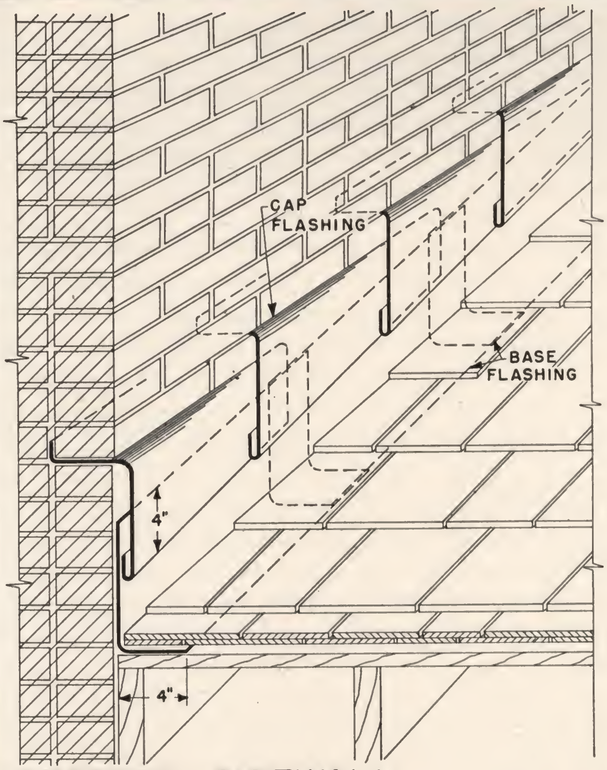
Fig. 67 shows a method of flashing when a shingle roof abuts a shingled wall. The flashing is carried up the wall sheathing at least 4″ under the shingles and secured along the upper edge by copper (copper-alloy) nails. On the roof the flashing extends out about 4″, and is held down with cleats, or R. H. brass screws, as in **Fig. 62,** spaced 12″ to 18″ on centers. Note the ½″ fold-back of the lower edge.

FASTENING COPPER TO BRICK MASONRY

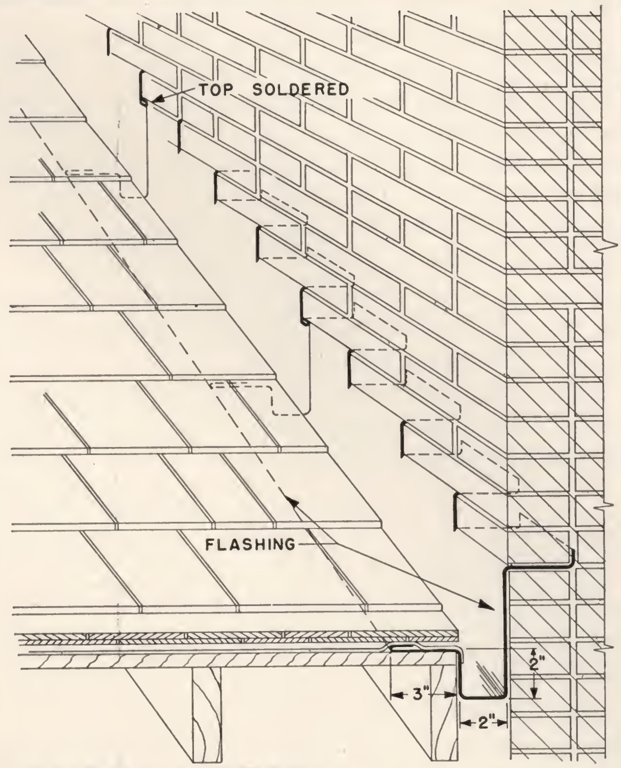
If flashings are installed after a brick wall is erected the joints are raked out 1½″ deep, and the metal pieces are turned into them, where they are held by 1″ lead plugs, or, as is standard practice in England, by small bits of copper folded and hammered into wedge shape. These are driven into the joint every 10″ or 12″, and beaten out to grip the flashing piece. The joints are then caulked with mastic, elastic cement, or lead wool.

Examples of this kind of fastening will be seen in **Figs. 69,** and **70, Plate XVI.**

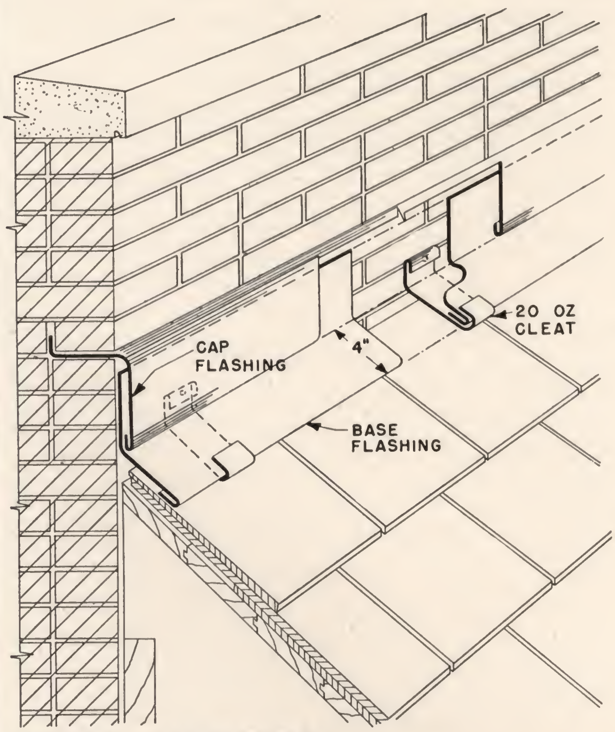
(*See also Note on Page 58.*)



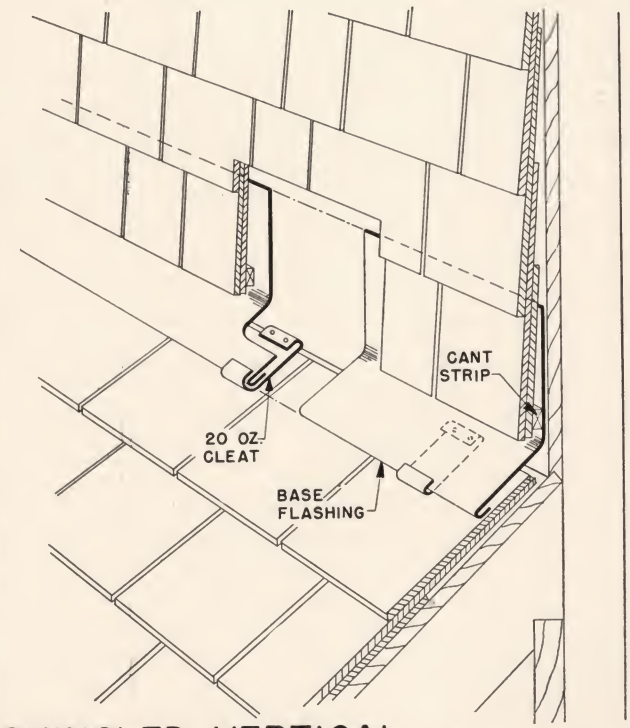
STEPPED SIDEWALL FLASHING-CAP & BASE FIG. 64



STEPPED SIDEWALL FLASHING - ONE PIECE FIG. 65



BRICK VERTICAL WALL FLASHING FIG. 66



SHINGLED VERTICAL WALL FLASHING FIG. 67

WALL FINISHES (Continued)

Fig. 68 shows a method of flashing when the wall at the top is of rubble stone. The wall is started in brick to form a level base for the flashing. After the flashing is placed, the stone is started on a thick bed of mortar. The flashing continues down over the roofing as in **Fig. 66, Plate XV,** and if necessary may be held against wind lifting as described in **Fig. 64, Plate XV.** The flashing is carried completely through the wall—a "through flashing" construction always used in masonry walls subject to moisture penetration when rainstorms are accompanied by driving winds.

It should be noted that copper is ductile enough to be worked without splitting into the uneven joints of rubble and uncoursed ashlar masonry.

TILE ROOFS

Fig. 69 pictures the method of flashing when a tile roof meets a brick wall at the side of the roof. The base flashing extends out on the roof just far enough to avoid puncture by the nails used to secure the tile, and is then turned up at right angles as high as the underside of the tile and cleated, thus forming a small trough. The base flashing is carried high enough on the brick so the cap flashing, when in place, will lap it at least 4″. The cap flashing is laid in the brick joints as the wall is built and stepped as required by the slope of the roof. Before being placed each end of the cap flashing should be folded back ½″ as shown.

Fig. 70 shows the flashing when a tile roof abuts a brick wall at the top of the roof. The construction is similar to that for a shingle roof shown in **Fig. 66, Plate XV.** The cap flashing laps the base flashing 4″, which extends out on the roof tile as far as the edge of tile top-fixture. Sometimes the copper is dressed down tightly over the tiles, or it may be held down by copper cleats previously nailed in the brickwork, as in **Fig. 66.** Sometimes the cleats are tucked under the tile top-fixture and soldered to the flashing.

Fig. 71 shows the method of flashing a dormer window or other vertical structure on a tile roof. The upper part of the drawing shows the flashing against the side wall, and the lower part the flashing against the front wall. In side wall construction the flashing piece is carried out on the roof and turned up against a wooden strip supporting the tile; it also turns up on the vertical wall as far as necessary (but never less than 4″), being nailed to the sheathing at 8″ intervals. The tile is kept a short distance from the wall so the flashing forms a small gutter. Provision must be made at the low point for connecting this flashing with the main gutter by continuing it under the tile to the eaves, or else it must run out on top of the tile.

On the front wall the flashing is placed against the sheathing and carried up at least 4″ over a cant strip used to start the bottom course of shingles. When a window occurs in the wall the flashing is carried well up under the window sill as in **Fig. 127, Plate XXXV.** The upper edge of the flashing is nailed to the sheathing with nails about 8″ apart. The lower edge extends out on the tile from 4″ to 6″ according to the slope of the roof, and is turned back on itself ½″ for stiffness.

Note how the building paper under the shingles laps over the top of the flashing piece a distance sufficient (4″ or more) to make a weather cut-off.

(See also Note on Page 58.)

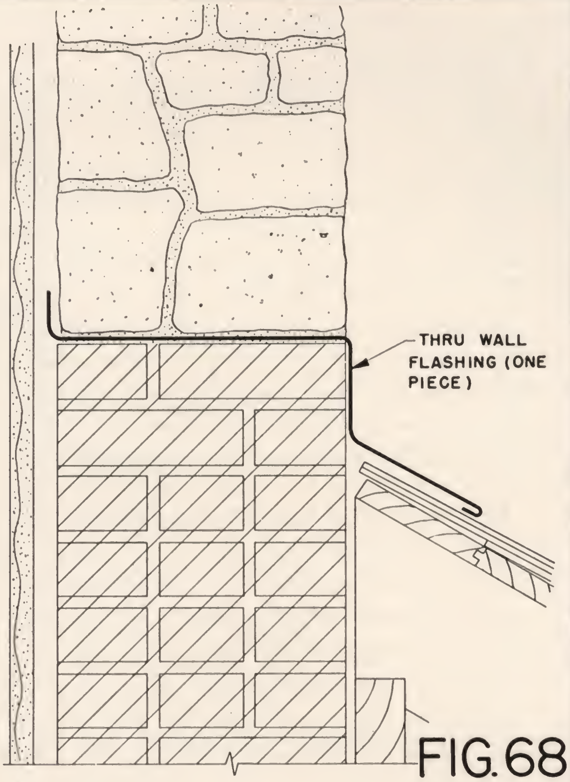


FIG. 68

RUBBLE WALL THRU FLASHING

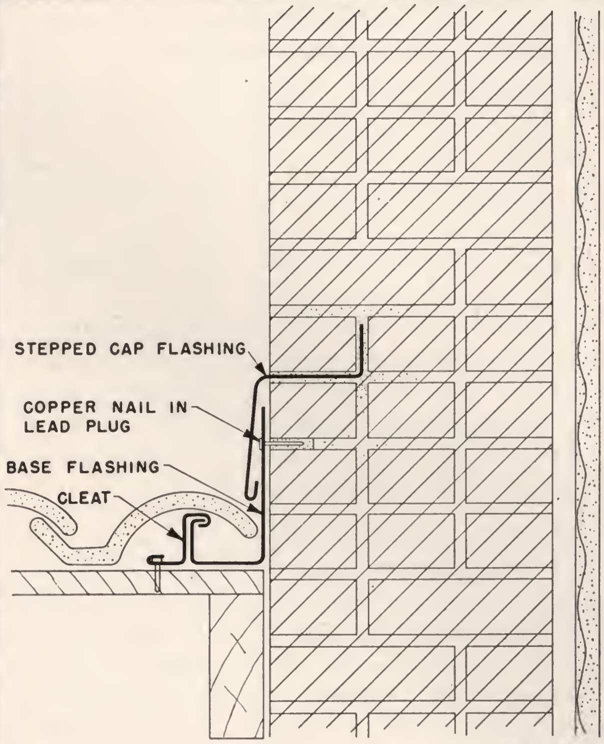


FIG. 69

SIDE WALL FLASHING
TILE ROOF AGAINST BRICK

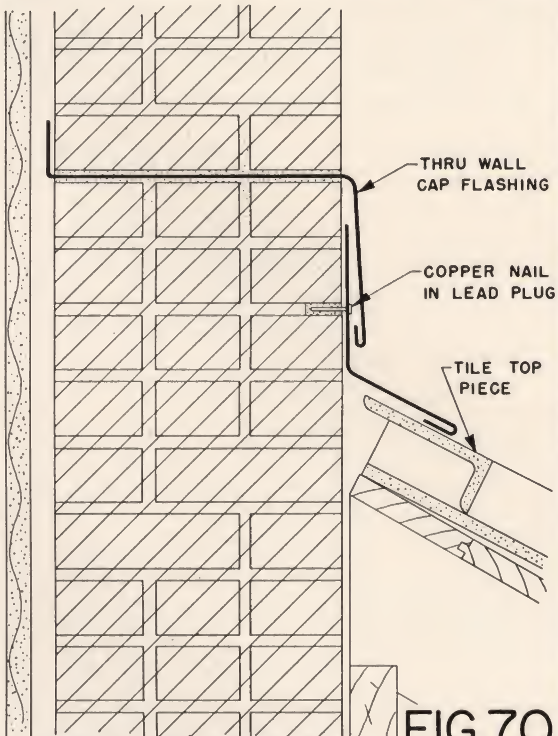


FIG. 70

THRU WALL FLASHING
TILE ROOF AGAINST BRICK

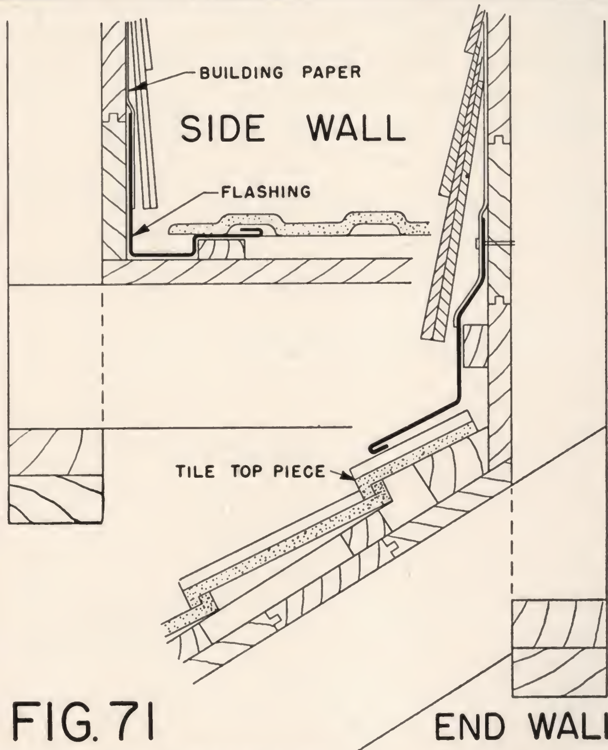


FIG. 71

WALL FLASHING
TILE ROOF AGAINST FRAME

WALL FINISHES (Continued)

COMPOSITION, OR BUILT-UP ROOFS

Special reinforcement of built-up roofing is desirable where it meets a metal base flashing. Three layers of felt, saturated with pitch, and extending 6″ up the walls and out over the roofing felt to lap 6″, 5″, and 4″ respectively, are applied in such cases. The base flashing is then rounded (not sharply bent) and set in the angle against these layers of felt. It can be nailed through to the roof sheathing, but what is considered a better means of fastening is described below and shown in **Figs. 72** and **74.** The flashing strip extends out on the roof at least 6″ and up on the wall at least 8″. Over the metal on the roof two plies of felt at least 15″ wide are laid. These are cemented thoroughly to each other and the roofing by hot pitch.

Fig. 72 shows methods of flashing when a compo or built-up roof abuts a wall covered with stucco. At the left is shown stucco on metal lath against wood sheathing; at the right appears stucco, or cement mortar, applied direct to hollow tile. Note that the base flashing detail is the same in each case. The stucco lath laps the cap flashing at least 2″. The base flashing is nailed to the wall sheathing, or secured to the masonry by copper (copper-alloy) nails in lead plugs. It extends out on the roofing at least 4″, where it is covered with roofing felt as described above. Transverse joints in the base flashing are ¾″ soldered flat-lock seams. The cap flashings are lapped 3″ and left unsoldered. The cap flashing laps the base by 4″.

In the right hand detail the cap flashing is carried through the wall and turned up 2″ at the back .

WATER TABLE

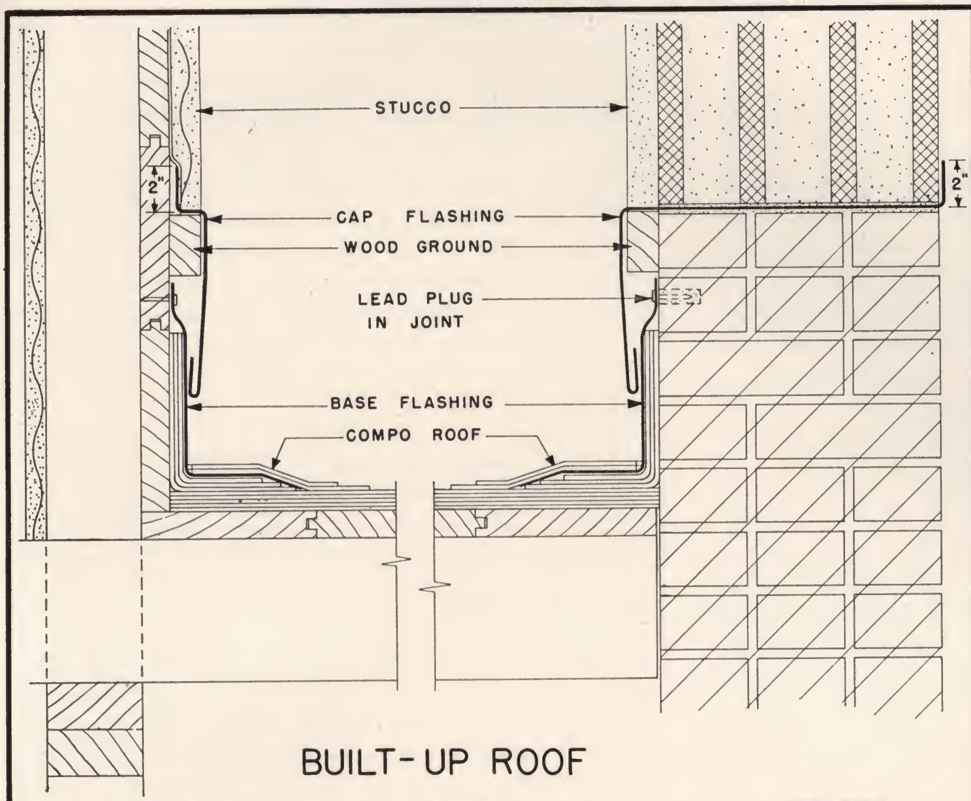
Fig. 73 shows a method of flashing the base of a frame building when a projection known as a "water table" is used. A brass edge strip is fastened to a horizontal wood member by brass screws (or nails). The flashing is hooked over it, and then extended up on the sheathing behind the cant strip, the nailing of which also holds the flashing piece. Note that the sheathing paper laps outside the metal.

A cheaper way of fastening is by nailing along the lower edge only. In either case a drip is provided to keep the wood dry and prevent rotting. When the bottom shingle course is single the flashing must go up the wall until it is covered by the second course.

Fig. 74 shows a method of flashing a set back in fireproof construction where the deck is covered with a composition roof. The junction of the roof surface and the upper wall must be flashed fully, not only against snow in northern climates, but because it virtually is impossible to build masonry walls impervious to driving rains. The cap flashing is carried through the wall. The base flashing is placed as in **Fig. 72** and is lapped at least 4″ by the cap flashing. The cross seams of the outer cap should be soldered flat-locks, held with cleats. The top edge of the base flashing is held by copper nails driven into lead plugs set into masonry joints at intervals of 24″ or so. For details of reglets see **Fig. 97** and **98, Plate XXVII.**

An alternate is a loose-lock seam instead of the cap and base flashing shown.

(See also Note on Page 58.)



BUILT-UP ROOF

STUCCO ON WOOD

FIG. 72

STUCCO ON MASONRY

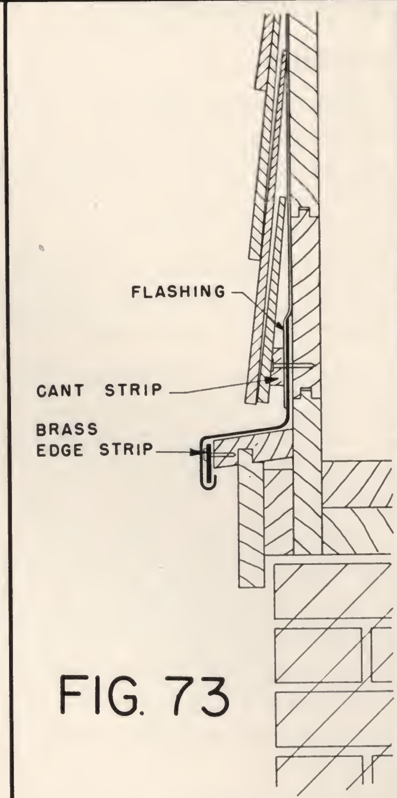


FIG. 73

WOOD WATER TABLE

SET-BACK IN FIREPROOF CONSTRUCTION

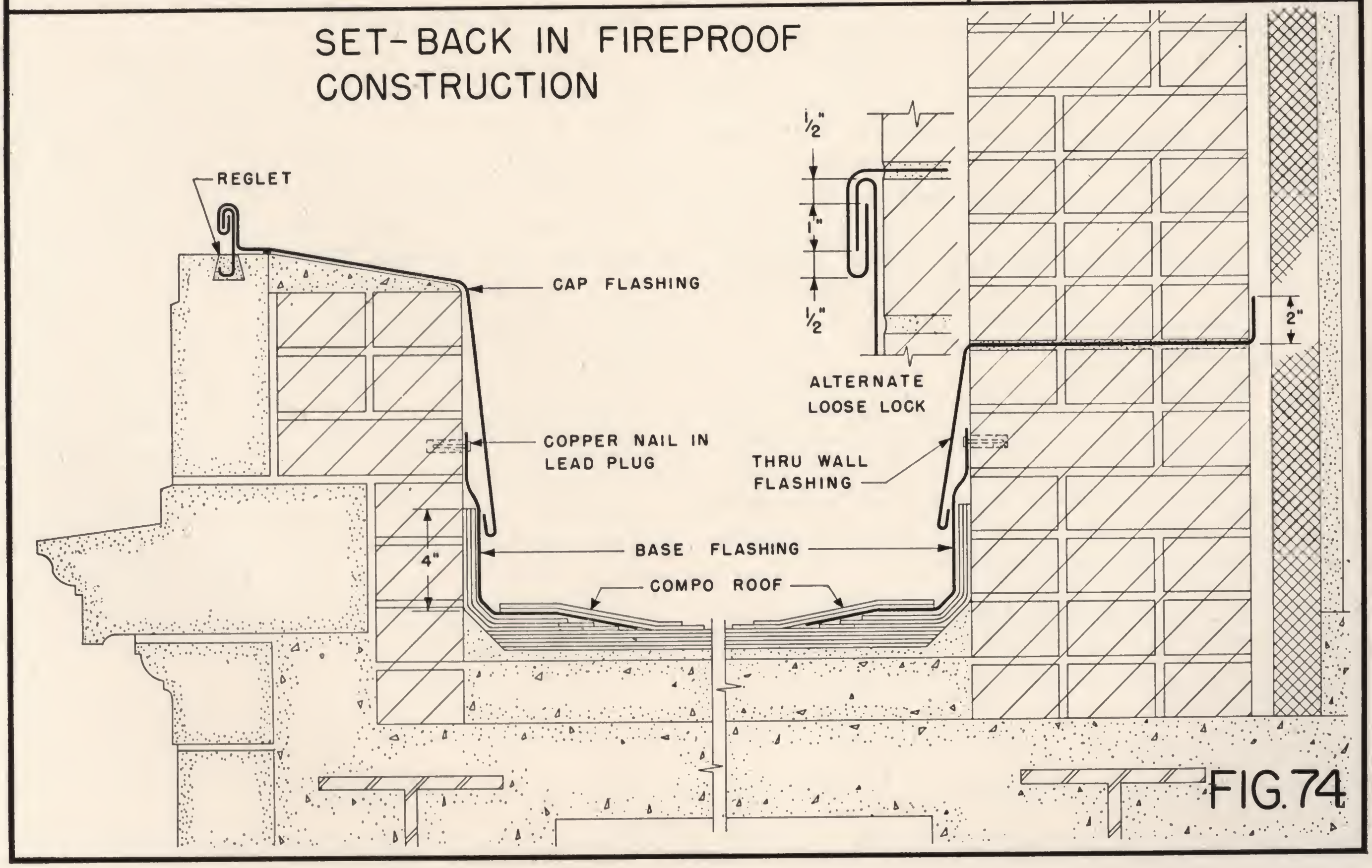


FIG. 74

WALL FLASHINGS

COPINGS

Figs. 75 and **76** present two of many good methods of covering the tops of walls with watertight copper copings. Because of the need of rigidity—the tops of walls being exposed to strong winds—they are made of 20-oz. or heavier copper. And if the wall is exceptionally wide they are formed with a V-joint running lengthwise. Cross seams are lapped and soldered, with loose locks filled with elastic cement or white lead every 30 feet, as in **Fig. 77.**

Fig. 75 shows the copper placed directly on masonry, the top of the wall having been buttered with mortar so as to give the surface a slight (about ¼″ per foot) inward slope. Longitudinal copper strips are built into the masonry as it is erected, or fastened by the conventional method of copper nails (brass screws) in lead plugs. (An alternate method is shown in detail **E** of **Fig. 79**). The edges (shown in finished position in the drawing) are left turned out at angles of about 90°, so that the coping pieces can be hooked over them and dressed down to form drips.

This detail also shows how flat-seam copper sheathing is carried up a wall and hooked into the coping piece and its fastening.

In **Fig. 76** the top of the wall is finished with a wood member. As shown it overhangs the masonry so that there is room to fasten the copper cover to the under sides of the projections by copper nails (or brass screws) spaced about 12″. Note how the coping piece is folded to form drips and to press tightly against the wall. In actual practice the flange against the wall would fit snugly, the bent lip being held tightly by its spring action.

When the top of the wall finishes flush—or nearly so—methods of fastening are shown in details **A** and **B** of **Fig. 78,** and in details **C, D, F, G,** and **H** of **Fig. 79.** Obviously all these methods are interchangeable.

OLD AND NEW WALLS

Figs. 77, 78 and **79** show methods of flashing between old and new walls. Where the walls are of uneven height, cap and base flashings are used. If the old wall is higher, as in **Fig. 78,** it is necessary to cut a reglet in the stone or to rake out a mortar joint to receive the cap flashing which is secured as described on page 27.

In new work, as in **Fig. 79,** the cap flashing is built into the masonry as it is erected. At **A, Fig. 78,** is shown a fastening used with walls sheathed with metal. The flashing is secured to the edge of the wood plate by brass screws and lead washers about 12″ apart. Additional, interchangeable, methods of fastening base flashings are shown in details **B** to **H** in **Figs. 78** and **79.** At **B** the flashing is nailed to the wood block and a fold formed which is turned down over the nails. The nails are about 12″ apart. **G** shows the edge strip method of fastening the flashing. The brass strip, ⅛″ thick, is screwed to the block and the flashing is hooked over it. This gives a stiff clean edge. The method **H** is simpler and less expensive than **G,** but is less rigid. The edge strip is formed of a nailed double-fold of copper.

Fig. 77 illustrates two excellent methods of fastening. The 1″ overhang at the sides allows the flashing to be secured on the protected under side. No edge strip is needed and the drip edge formed in the flashing keeps the wash from the wall. The screws or nails are about 12″ apart.

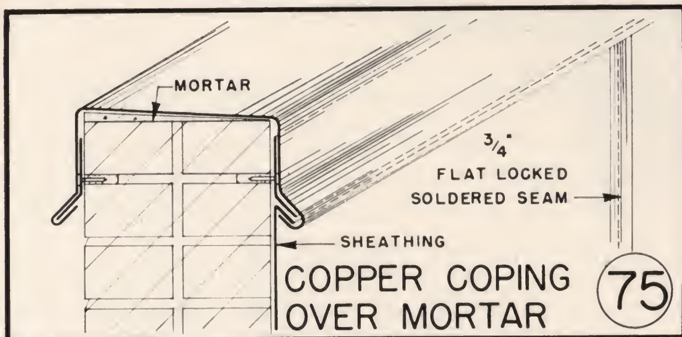
Fig. 77 also shows the construction when walls finish at the same height. If the width of the copper cap sheet exceeds 24″, a crimp or standing seam is provided at the center to permit movement, or the length of the sheets is limited to 36″, so that the soldered cross seams can act as stiffeners.

DRIPS AND EDGE STRIPS

Throughout these plates, in places too numerous to list, appear various methods of forming drips and edge strips. The method used is not as important as the results accomplished. These are twofold: (1) to keep water off the face of buildings; (2) to provide a watertight joint that allows complete freedom of movement. A few proven ways are shown on **Plate XVIII.**

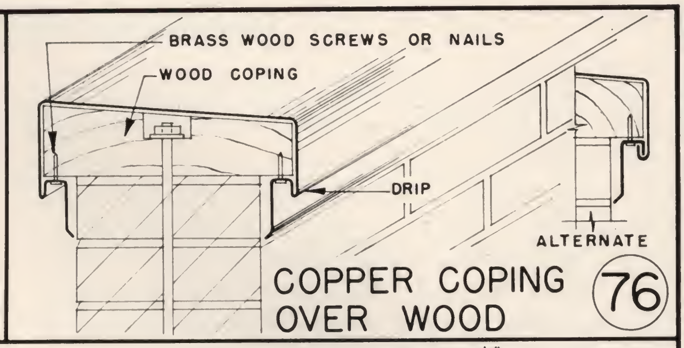
Such construction is necessary at the outer edges of walls, cornices, and all other projections. As illustrated in **Figs. 75, 76,** and **77** it often is possible to form the flashing itself into a drip. Methods employing separate fastenings are shown in **Figs. 78** and **79.** Nails or screws should be, preferably 8″, but not more than 12″ apart.

On long walls expansion is taken care of by loose-lock caps, as shown in the lefthand detail and the two sections at the right of **Fig. 77.** To keep out driving rain the flat (top) portion of this loose lock is filled with white lead or mastic. Note that the principle here is the same as that expounded on page 58.



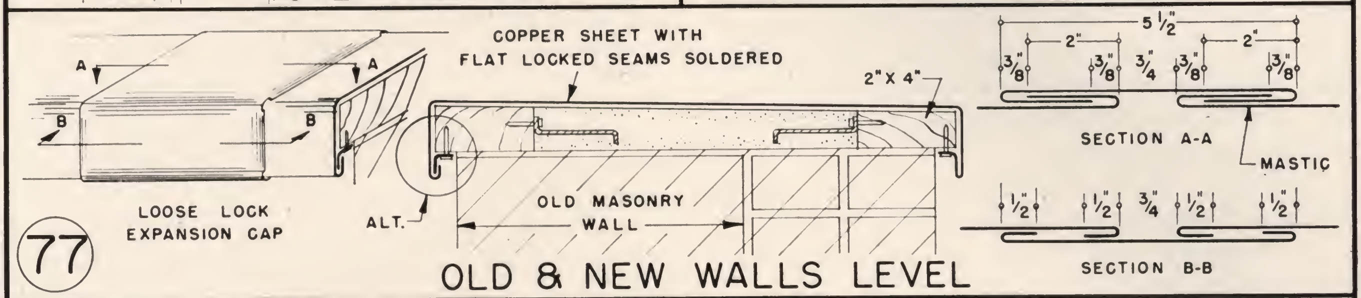
COPPER COPING OVER MORTAR

75



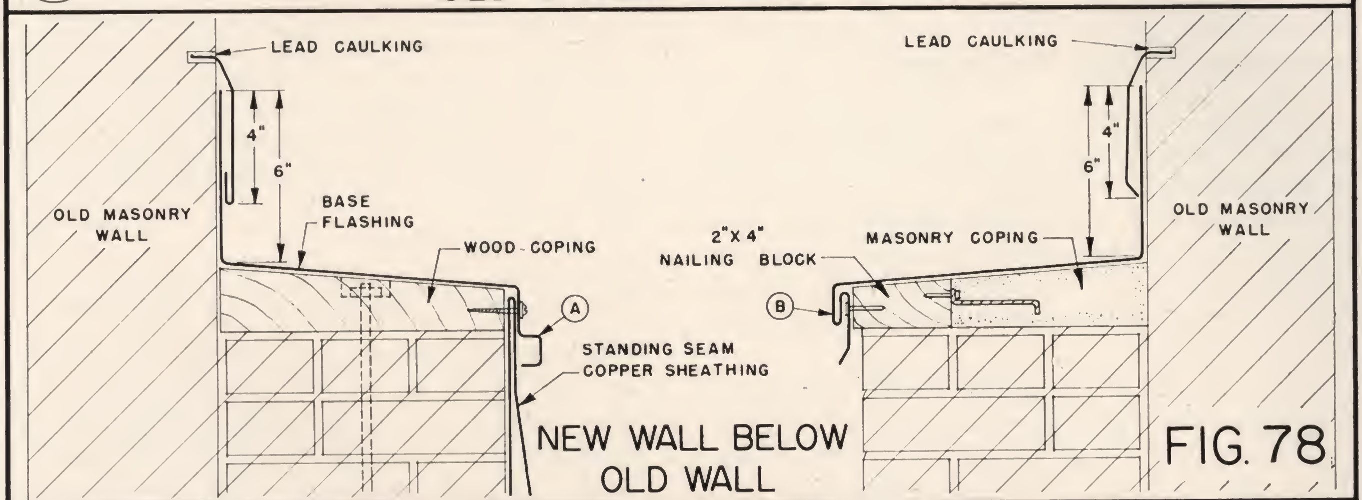
COPPER COPING OVER WOOD

76



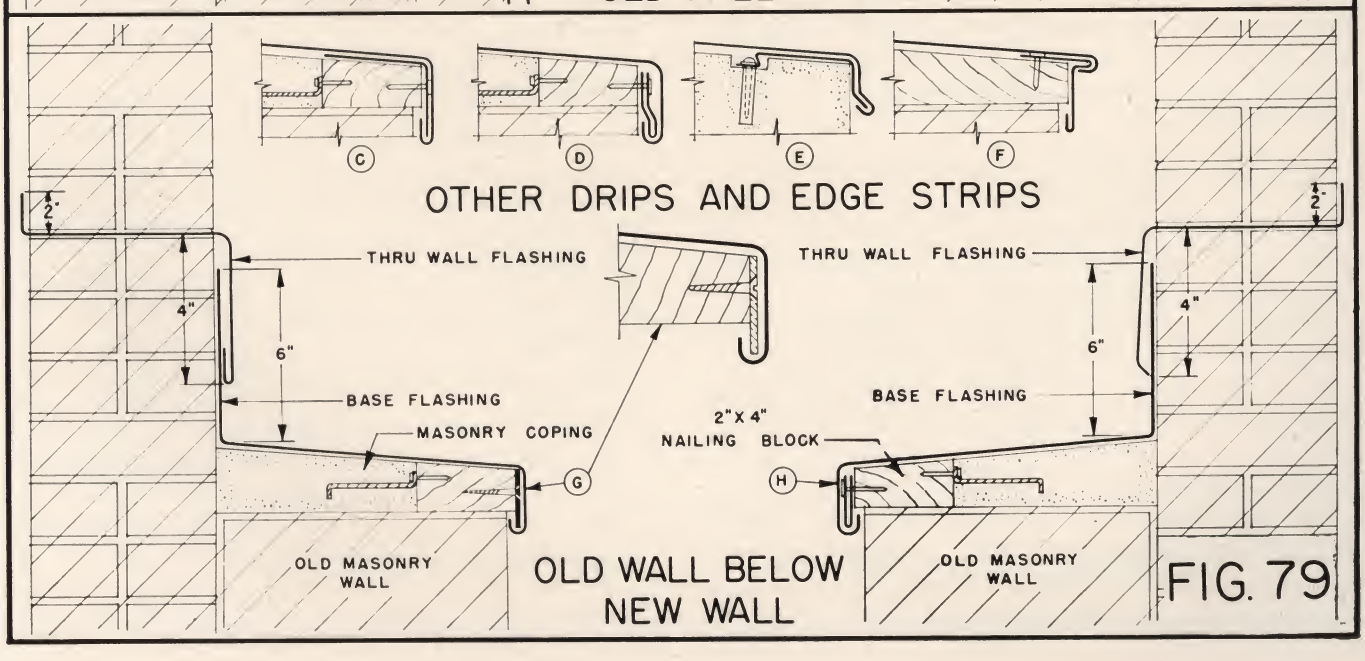
77

OLD & NEW WALLS LEVEL



NEW WALL BELOW OLD WALL

FIG. 78



OTHER DRIPS AND EDGE STRIPS

OLD WALL BELOW NEW WALL

FIG. 79

THROUGH-WALL FLASHINGS

The three Plates **XIX, XX** and **XXI** on pages 77, 79, and 81 illustrate some of the places in exterior building walls where leaks are likely to occur and a complete metal barrier, or THROUGH-WALL FLASHING, is needed. With one or two exceptions the 32 details on these Plates are not described, as has been done with the other Plates, because in this instance such descriptions are not deemed necessary. The Plates are intended to demonstrate *where* and *how* through-wall flashings are used, rather than *how* they are installed. There are so many variations in structural details that a description of the application of through-wall flashings in a few cases will serve no useful purpose.

Accordingly, the text that follows on this and pages 78 and 80 covers the subject in a general way only.

WHY THROUGH-WALL FLASHINGS?

Masonry structures, built centuries ago, and still in use, have no through-wall flashings. Why are they necessary in modern building construction? The answer is found in the changes in structural design that have taken place with the use of structural steel. Thick and solid bearing walls have been replaced by thin curtain walls, through which wind-driven rain, aided by a natural capillarity, can quickly penetrate.

In the 18th Edition of the Kidder-Parker "Architects' and Builders' Handbook" appears the following statement.

"Because of the gradual reduction in thickness of exterior walls and the use of hollow-tile construction, wind-driven rain and moisture enter the structure through the face brick and mortar joints. The result is the formation of water pockets which eventually make contact with ceiling and wall plaster."

Moreover, masonry walls, even though the component parts be in themselves waterproof, cannot be regarded as permanently impervious to wind-driven water. The gradual shrinkage of materials, and the natural movement of a building, are common causes of leaks.

Therefore it is necessary to have permanent water-barriers at all places where rain water and moisture entering the exterior of a wall can work through to the inside, or come in contact with wood or steel members in the wall.

The penetration of water through walls is one of the principle problems of structural designers. Copper through-wall flashings provide what is probably the most satisfactory answer—all things considered—to this problem of permanently preventing leaks.

MODERN THROUGH-WALL COPPER FLASHINGS

Today through-wall flashing is done with sheets of copper specially deformed by ridged, ribbed, or embossed, patterns (or combinations) so that mortar can fill the depressions in the sheets and form keys in all directions,—laterally, transversely and vertically. There are several types on the market, the most satisfactory of which provide in addition to the three-way mechanical bond, a dam or barrier that prevents water from collecting on the sheet.

Such sheets are stiffer than plain copper, and require no soldering. The ends lock and hook together to form watertight joints and the deformities take care of expansion and contraction.

Masonry bond tests have demonstrated that the mortar forms a positive mechanical bond that fails only when the mortar shears.

Plain sheet copper lacks this attribute. The smooth metal destroys the masonry bond and weakens the wall. Nor are crimped or otherwise deformed sheets that provide only a horizontal bond much better. The use of plain or crimped copper for through-wall flashings is not recommended.

TWO KINDS OF THROUGH-WALL FLASHINGS

Through-wall flashings can be grouped in two classes: (1) Flashings that go through and extend beyond the wall; as all except **E** and **J** in **Fig. 80, Plate XIX**; (2) Flashings entirely concealed in the wall; as **G, H, J, K** in **Fig. 81, Plate XX**, and all in **Fig. 82, Plate XXI**.

WEIGHT OF COPPER

Class (1) flashings should not be lighter than 16-oz.

Class (2) flashings are made of lighter copper, 10-oz., 6-oz. and copper-covered membrane. But it must be borne in mind that light-weight copper is not to be used for concealed flashings that are likely to be subject to tensile stresses due to unequal movement of various parts of the supporting structure.

The maximum widths of sheets for the various thicknesses are:—

3-Way Bond Flashing:	—16 oz.	36 Inches;
" " "	—10 oz.	36 " ;
" " "	— 6 oz.	16 " ;
Copper-Covered Membrane	— 3 oz.	60 " ;
" " "	— 2 oz.	60 " ;
" " "	— 2 oz.	60 " .

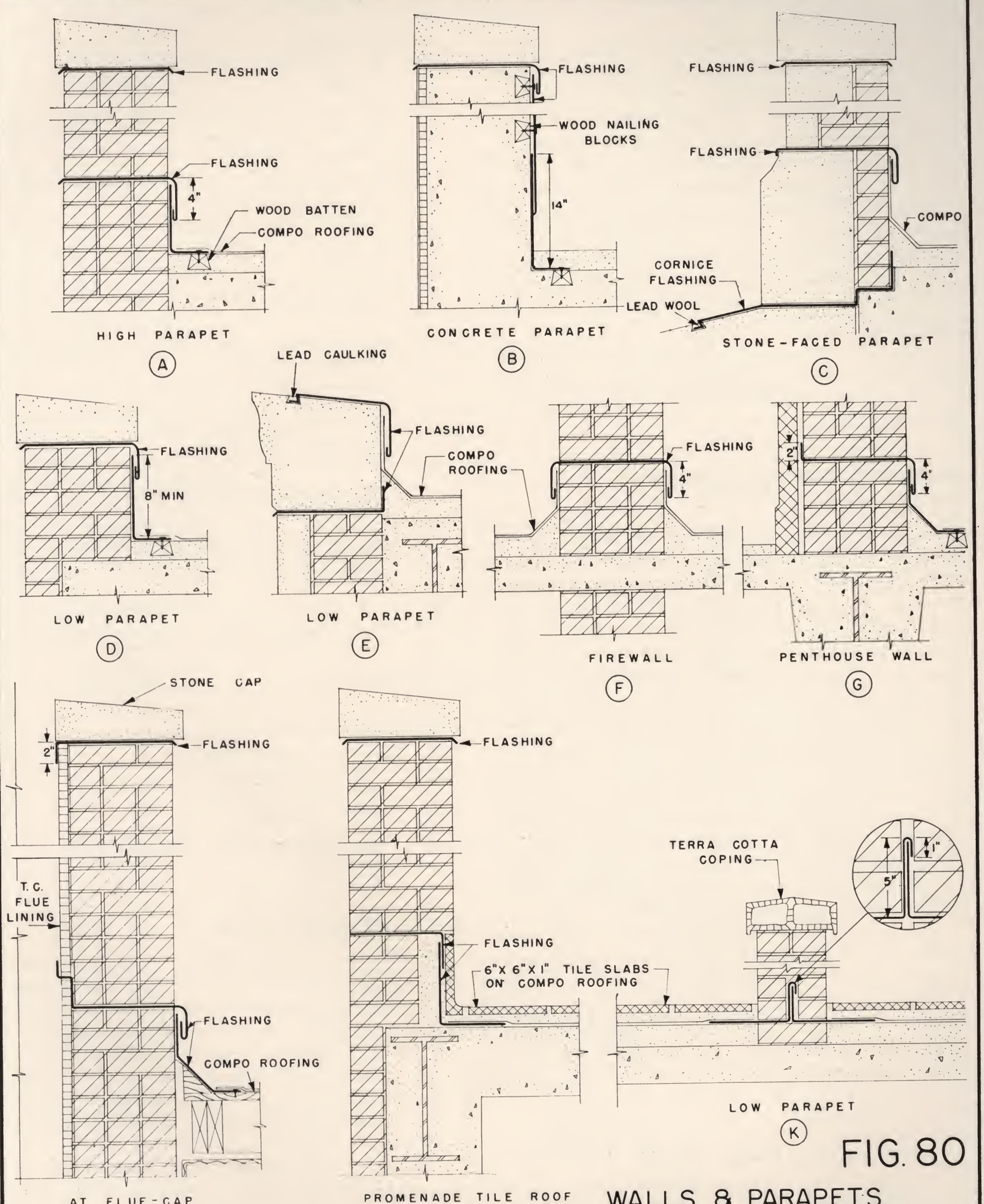


FIG. 80

WALLS & PARAPETS

THE USE OF THIN, LIGHT-WEIGHT COPPER IS LIMITED

The use of thin copper for concealed flashings is illustrated in **Fig. 82, Plate XXI.** It finds wide application, either as 6-oz. or membrane, for waterproofing spandrels, as in details **A, E, F, G,** and around window and door openings, as in details **A, B, C, D, E, F,** and for cavity-wall construction, as in detail **H.** See also **Plate XXXV** for details of its use with wood frame construction.

Where copper membrane is specified we recommend not lighter than 3-oz. sheet bonded with asphalt to a backing of bituminous-impregnated building paper creped to take care of thermal movement. This combination is very tough and flexible. It can be formed and folded by hand without fracture.

Such sheets are excellent for dampproofing the keyed joint between footing and foundation wall, and the vertical joint between foundation walls and floor slabs resting on the ground.

WHERE THROUGH-WALL FLASHINGS ARE INSTALLED

In general through-wall flashings are needed under copings; at the bases of all parapets and walls that adjoin or penetrate roofs (See **Fig. 80—F, K**); side walls at every floor level; and all openings in walls.

It is in walls above the roof line that the greatest weakness is found. With both faces exposed to the weather, either side of the wall is subject to driving rain while, on the other side, the partial vacuum always present in the lee of a wind-break exerts a powerful suction that aids the natural capillarity of the masonry in absorbing water. Meanwhile water flowing through the joints of the coping enters the masonry by gravity. The water thus accumulated seeps down and in until the saturation point of the masonry is reached; then it flows off both faces of the wall, to the detriment of the supporting structure, plaster and decorations on the inside, and the defacement of the outside by the precipitation of mineral salts.

Through-wall flashings installed under the coping and at the base of the parapet intercept this accumulation and divert it to the roof or outside face of the wall.

More specifically, flashings are installed at the following locations in exterior masonry walls. Where these are illustrated in the Plates they are so designated by Figure Number and Detail Letter.

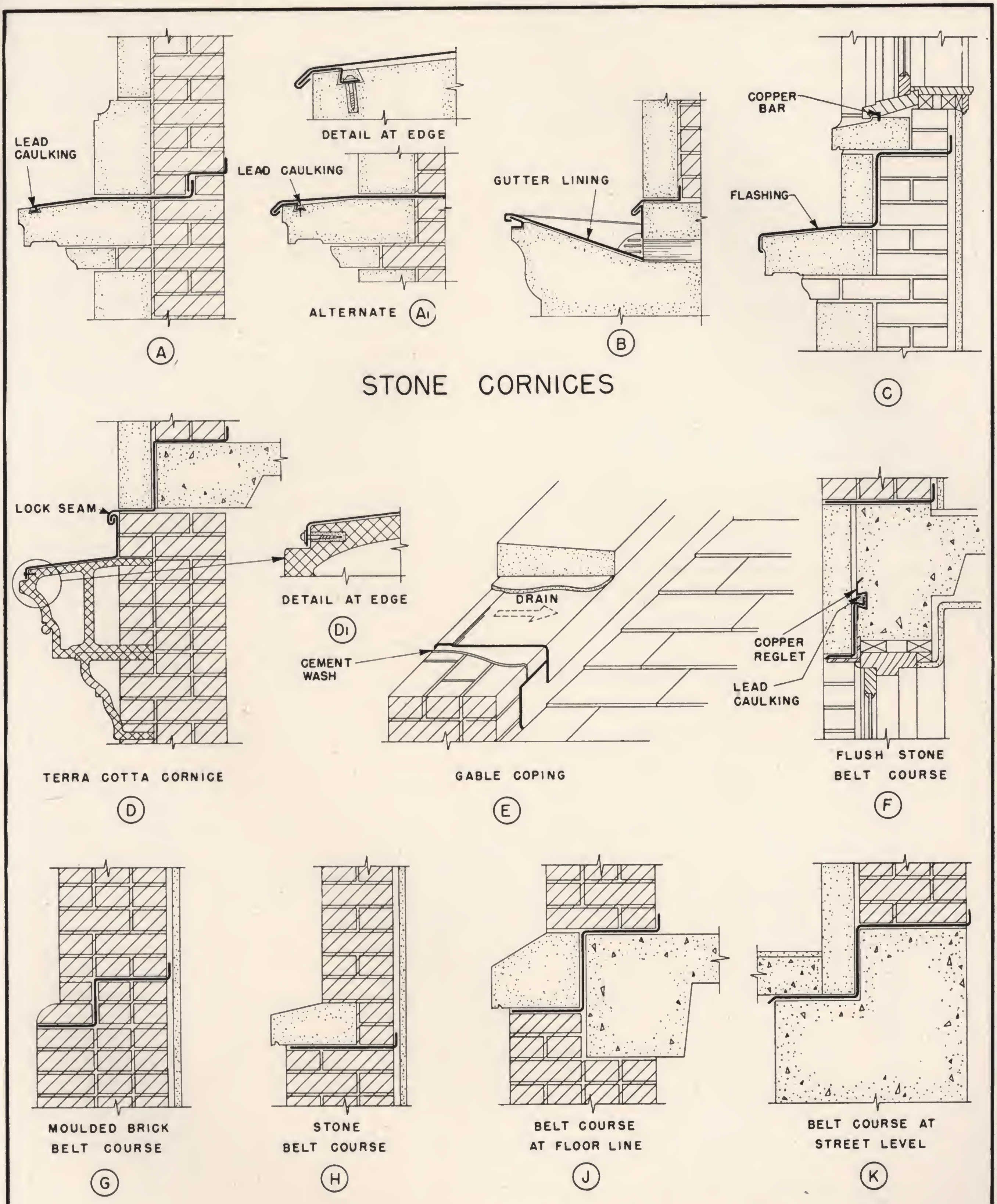
LOCATION	SEE DETAIL
1. Under masonry copings	**Fig. 80—A, B, C, D.** **Fig. 81—E.**
2. Over roof base flashings	**Fig. 80—A, B, C, D, F, G, H.**
3. Over cornices	**Fig. 81—A, B, C, D.**
4. Over projecting belt courses	**Fig. 127—0.**
5. Under belt courses that do not project beyond the face of the wall	**Fig. 81—F.**
6. Over and under wood or metal belt courses that do not project beyond the face of the wall	(Not Illustrated)
7. Under masonry sunken belt courses	**Fig. 81—K.**
8. Under belt courses where the wall thickness is reduced	**Fig. 81—G, H, J.**
9. Over doors, windows and other openings	**Fig. 82—A, B, C, E, F.**
10. Under sills	**Fig. 82—D, G, H.**
11. Over and under niches, etc.	**Fig. 82—K.**
12. Over and under plaques and ornaments built into walls	(Not Illustrated)
13. Over spandrel beams and other horizontal steel members in walls	**Fig. 80—G, J.** **Fig. 82—A, E, F, G, H, J.**
14. Over reinforced concrete beams in walls	**Fig. 81—J.**
15. Between the top of concrete foundation walls and the bottom of masonry building walls	**Fig. 81—K.**
16. Under masonry chimney caps	**Fig. 80—H.**

NOTES ON INSTALLATION

The following general notes on installation, with their references to details that illustrate the points discussed, are set down with the idea that they may help in the preparation of plans and specifications for flashings.

It will be noted that a turn-up of at least 1″ is called for at the back edge of the flashing piece, as in "D" below. To assure that this important water-stop actually finishes 1″ high, many specification-writers call for a turn-up of 2″.

A—Through-wall flashings should always be set in a bed of mortar, both *over and under* the metal, and sloped in the direction the water should drain. **(Fig. 81-E).** (*continued on page 80*)



CORNICES & BELT COURSES FIG. 81

B—Special cover pieces should be used with all "3-way bond" flashing pieces. If not, the corner joints should be soldered.

C—At columns and pipe chases the flashing should be turned up at least 1″ and have the corners lap-soldered.

D—Cap flashings should turn up at least 1″ on the inside face of the wall, extend through the wall, and turn down at least 4″ over the roof base flashing **(Fig. 80-G)**.

E—Cap flashings at parapets should extend from the exterior face (with a ½″ drip at the outside) through the wall and down at least 4″ over the roof base flashing **(Fig. 80-A)**.

F—Cap flashings at chimneys should turn up at least 1″ against the flue lining (preferably finishing in a joint as in **Fig. 113, Plate XXX)**, extend through the chimney masonry, and turn down at least 4″ over the roof base flashing. All joints in this flashing should be soldered **(Fig. 80-H)**.

G—Flashings under copings should be the full width of the wall with ½″ drips on both faces **(Fig. 80-J)**.

H—Flashings over cornices on belt courses should turn up at least 1″ on the inside face of the wall, extend through the wall and out over the cornice, to finish with a drip at the outer edge **(Fig. 81-C)**. On wide cornices the flashing should be in two pieces **(Fig. 81-D)**.

I—Flashings under belt courses should turn up at least 1″ behind the belt course and extend to the exterior face of the wall **(Fig. 81-H)**.

J—Flashings under sills should turn up at least 1″ inside the wall and extend to the exterior face, or be turned down to form a ½″ drip **(Fig. 82-D)**.

K—Flashings over lintels, spandrel beams, and beams that end in the wall, should turn up at least 1″ on the inside face of the wall, extend through to the outside of the beams, down to the bottom of the beams, and then out to the outside face of the wall to finish flush or be turned down to form a ½″ drip **(Fig. 82-F)**.

L—Flashings between the top of concrete foundation walls and the bottom of masonry building walls should turn up at least 1″ on the inside face of the wall and extend through the wall to the outside face **(Fig. 81-K)**.

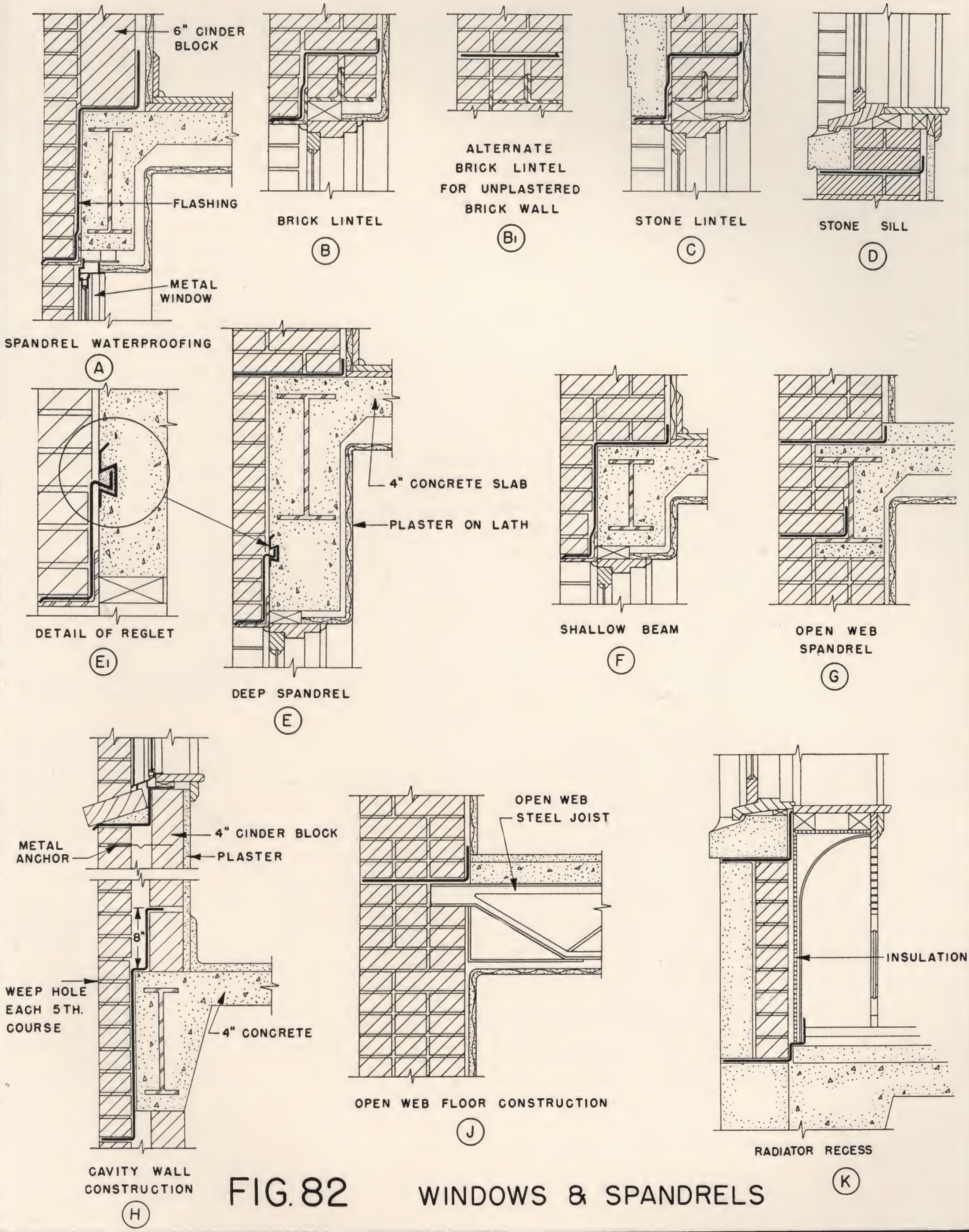


FIG. 82 WINDOWS & SPANDRELS

STRUCTURAL EXPANSION JOINTS

The expansion and contraction that occurs in long structures are important factors in their design. A steel and concrete building 100 feet long will develop a maximum movement of 3/4″ in a temperature range of 150°, assuming 40° of superheat. This movement is taken care of by specially designed expansion joints that are, in fact, complete transverse breaks in the framing and shell of the structure. These open joints are sealed against the weather by flexible covers so formed that they will stretch out as the temperature drops and compress as it rises. A complete seal for such structural expansion joints is the V-type cover shown in **Fig. 83.**

First of all the total amount of movement is determined, so that the width **X (Sec. B-B)** will be, at the time of installation, enough to permit the full calculated expansion.

Curbs not less than 8″ high are formed in the roof on both sides of the expansion joint. They are finished with wood plates bolted to the masonry and sloped about 2″ to the foot.

The base flashings **Q** and **S** extend out on the roof 4″ and are nailed to nailing strips as shown, or are built into the plies of roofing felt as in **Figs. 72** and **74, Plate XVII. Q** extends up the outside (parapet) wall far enough to be covered by the through-flashing piece **P.**

The base flashings **S** extend up the curb and join the cover **H** in a 3/4″ loose lock, which is held in place by cleats spaced 12″. (**Sec. B-B**).

These base flashings are made in 8′ lengths joined with 3/4″ locked and soldered seams, except that every third joint (24 feet) is made with a 3″ loose-lock filled with elastic cement or white lead (**Fig. 77, Plate XVIII**).

The piece **P** is continuous along the parapet wall, as is the coping piece **N,** except as both are cut to permit the placing of the lock strips **T** and the cover **R.** The coping piece **N** is used only on high walls (over 24″) or where the wall is subject to continuous driving rains and freezing weather.

On the curbs the V-type cover **R** (which is made of 20-oz. soft copper) is made in 8′ lengths with 6″ unsoldered lap joints. At the outside (parapet) wall it turns up (see **Sec. C-C**), passes over the top of the masonry through a slot left in the coping course, and continues down the outside of the building with 2″ laps every 8 feet, being built into the masonry as shown in **Sec. A-A.** The joint is finally filled with a caulking compound.

As the cover is fully exposed on the inside face of the parapet wall it must be secured and made watertight. While this can be done in several ways, probably the best —but not least costly—way is that shown. Lock strips **T** (of 20-oz. soft copper) are built into the masonry, and to these the cover **R** is secured by the flat cap strips **M** (also of 20-oz. soft copper) by means of loose-lock seams with enough lap to take up the movement of expansion and contraction.

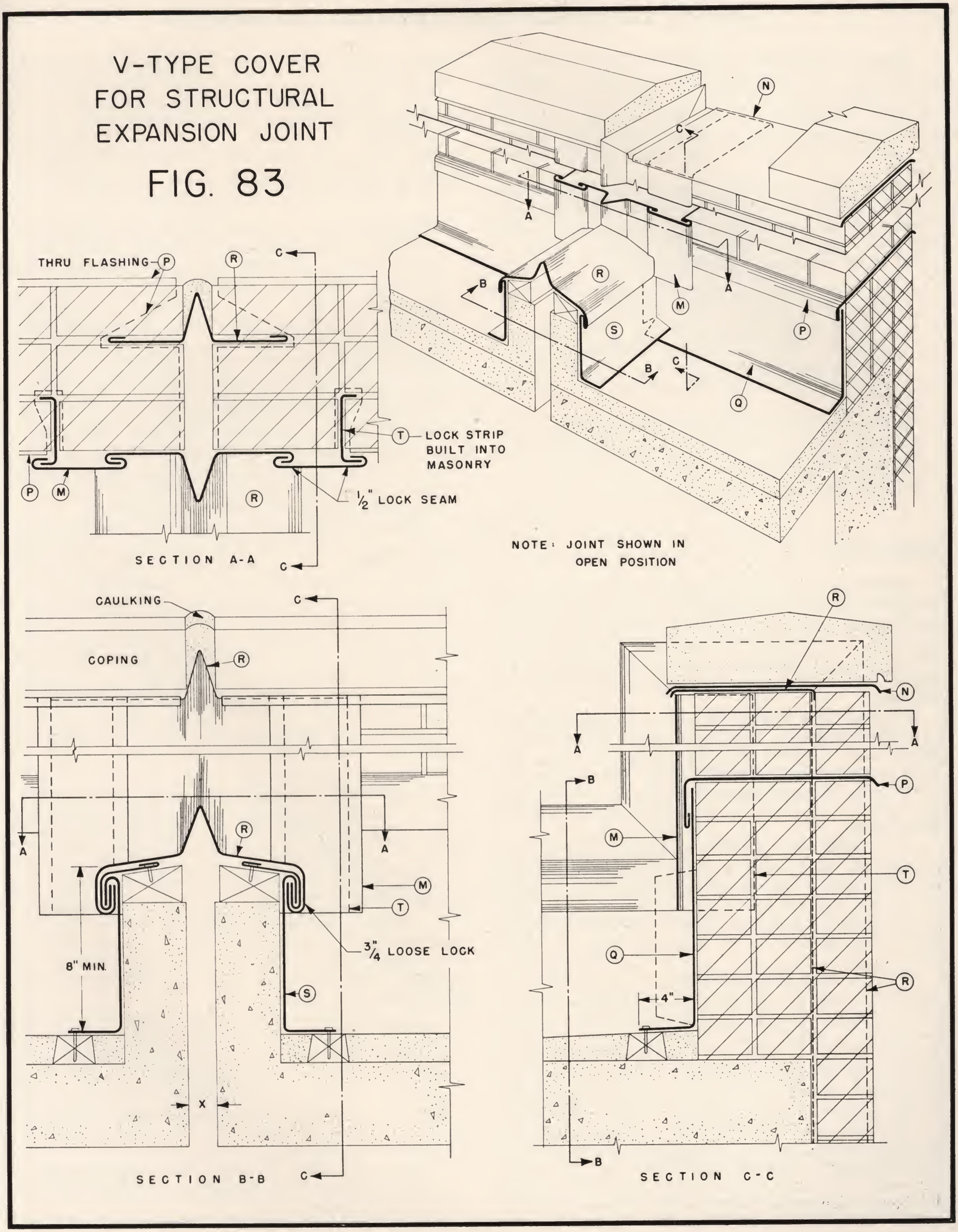
Under the coping the flanges of **R** are folded over and locked to separate pieces (shown by dotted lines in the isometric drawing), soldered to **M,** extending through the wall and carried along it to the lock strips **T.**

The masonry on the exterior face of the wall at the expansion joint is tied or bonded to the interior masonry. Copper wall ties (not shown in the drawings) are recommended for this.

The cover piece **R,** the cap strips **M,** and the lock strips **T** are made of 20-oz. *soft* copper. The rest of the metal is 20-oz. cold rolled.

V-TYPE COVER FOR STRUCTURAL EXPANSION JOINT

FIG. 83



EAVES, GUTTERS AND EXPANSION JOINTS

Methods of finishing copper roofs at eaves and their connections with gutters have been described in **Section II—Roofing.** Flashing details for other types of roofing draining into gutters are here discussed, and, since the methods are involved to a large degree with the construction of the gutters themselves, the two subjects are treated as one.

The construction of copper gutters, and of built-in gutters particularly, presents more difficulties and gives more trouble than any other phase of sheet-metal work. Below are listed certain cardinal principles that must be kept in mind by the designer and installer.

1. Flashings and gutters are not meant to store water, but to carry it away as fast as possible.
2. Gutter cross-sections must be such as to prevent the expansive thrust of ice from splitting the seams: The top shoulder should be wider than the bottom, and the depth less than the bottom width (See page 116).
3. Always install copper work so that it is free to move.
4. Design so that, where possible, joints can be loose-locked and soldering avoided.
5. Avoid nailing through copper sheets.

CANT STRIPS

Installation specifications issued by manufacturers of slate, shingles, and tile invariably call for a cant or other starting strip under the starting course, at and parallel to the eaves. If the flashing is carried under this cant strip, the latter should be held by copper straps soldered to the flashing. Nailing the strips, of course, would puncture the flashing.

There are three general methods of handling the cant strip with shingles or slates. In each the flashing is continuous and is carried under the shingles as far as possible to permit cleating just below the first nailing. The lower end of the flashing is locked to the gutter lining, or if there is no gutter, to an edge strip (See **Fig. 79, Plate XVIII**).

(1) In **Figs. 84** and **85** a wood strip is placed over the flashing. This is made of hard wood smoothly finished and secured by 2″ copper straps soldered to the flashing at 2″ intervals. As shown in **Fig. 85,** it is laid at a slight zig-zag to the eave so as to permit moisture forming on the roof above to drain off. Weeps, or slots, are cut at the low points.

(2) The wood strip is sometimes placed before the flashing is installed. This has these advantages: the strip can be nailed down; as it is protected by the flashing the quality of wood is not so important; there is easier drainage for any moisture that might collect under the shingles. On the other hand, it has the disadvantage that the shingles may be in contact with the flashing, presenting a chance for line-corrosion (see **Fig. 54, Plate XI**).

(3) In **Fig. 54, Plate XI,** the cant strip consists of a folded or crimped copper strip soldered to the flashing. The crimp slants slightly in the direction of the roof slope. The metal strips are laid in 4′ sections, with ½″ openings left between lengths as outlets for any moisture that may collect above the cant strip. Drainage also is facilitated by laying the strips at a slight angle with the horizontal.

Yet another variation of cant strip is shown by the **Alternate Cant Strip** detailed in **Fig. 85.** This is for use on steep roofs only, as cant strips are not set back more than 4″ from the edge of the bottom shingle course, and this strip is held by screws that also secure the cleats that hold the flashing strip or gutter edge.

Fig. 84 shows one method of forming a molded gutter and securing it to a shingled roof. The upper or roof edge is turned back on itself ½″ to engage copper cleats about 12″ apart, which are nailed to the roof with copper (copper-alloy) nails. To the outer edge, or roll, of the gutter are riveted long copper straps of 3/16″ metal, about 30″ apart, and extending up on the roof 3″ or 4″ above the inner edge of the copper gutter. Each strap is secured to the roof by two brass wood screws or nails. Copper or brass spikes, driven into the rafter ends from the outside edge, and through copper spreader sleeves, are also used as fastenings, as in **Fig. 101, Plate XXVIII.** While it is desirable that this form of gutter be supported from below as well as from above, this is not vital. But such gutters should be set far enough below the eave line to preclude damage from snow sliding off the roof.

When the gutter length exceeds 30 ft. expansion joints are necessary. They are made as shown, one end piece being folded over to form the sliding cap that covers the open space between the ends. The gutter is fixed at the outlets, the expansion joints being set midway between them, or at the far end in case there is but one outlet.

In long runs of molded gutters it sometimes is necessary to install inner linings to get the proper slope to the outlet. The gutter itself must hang level and true to form the cornice. Such inner linings are formed of not less than 16-oz. copper to fit the gutter contour and are set and soldered to the sides to provide a sloping floor, the high point being at the expansion joint.

Fig. 85 shows another type called a "Pole Gutter," known in some localities as a "Gutter-Strip". It finds wide use on the plain gabled roofs of medium-low-priced houses because it is cheap, easy to install, and gives long service.

A 2″ x 4″ wood "pole" is run parallel to the eaves, over which the copper is formed. Drainage is provided by a gusset in the gutter sloped to the leaders. The flashing is in two pieces (except **Alternate B**), loose-locked together, and cleated to the lower side of the pole on the top, or just under the top outer edge. The lower piece laps the shingles below the pole at least 4″ and has its lower edge turned back ½″ for stiffness.

Alternate methods of fastening are illustrated in details **A, B, C,** and **D.** In **C** the lower flashing piece is held only by cleats nailed to the pole and hooked opposite to the usual way. In **D** the shingle nails serve to hold the flashing. Details **A, B,** and **C** omit the roof covering (usually asphalt strip shingles) below the pole. Note that **A** and **B** do not, while **C** and **D** do, provide a water cutoff along the bottom of the pole.

The shingles along the upper edge laps the copper at least 4″, and the copper is covered by at least two thicknesses of shingles.

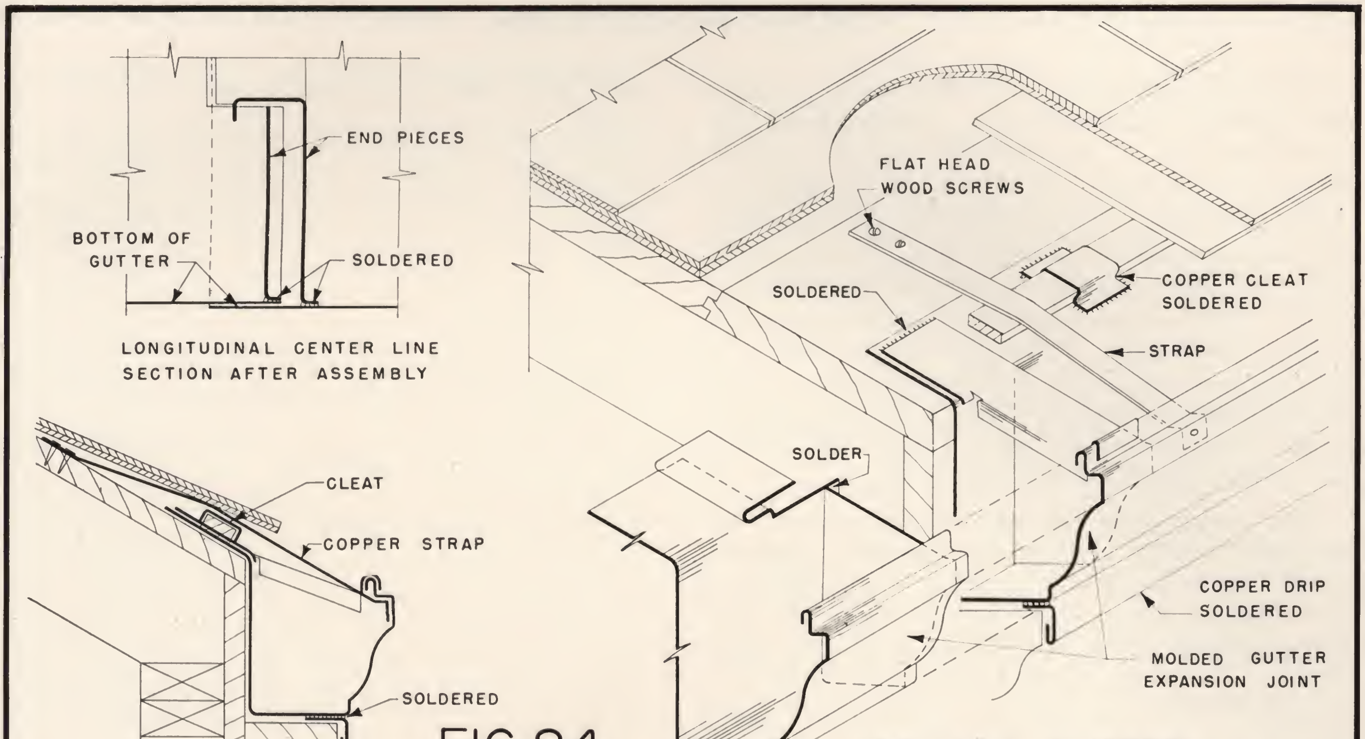


FIG. 84 MOLDED GUTTER

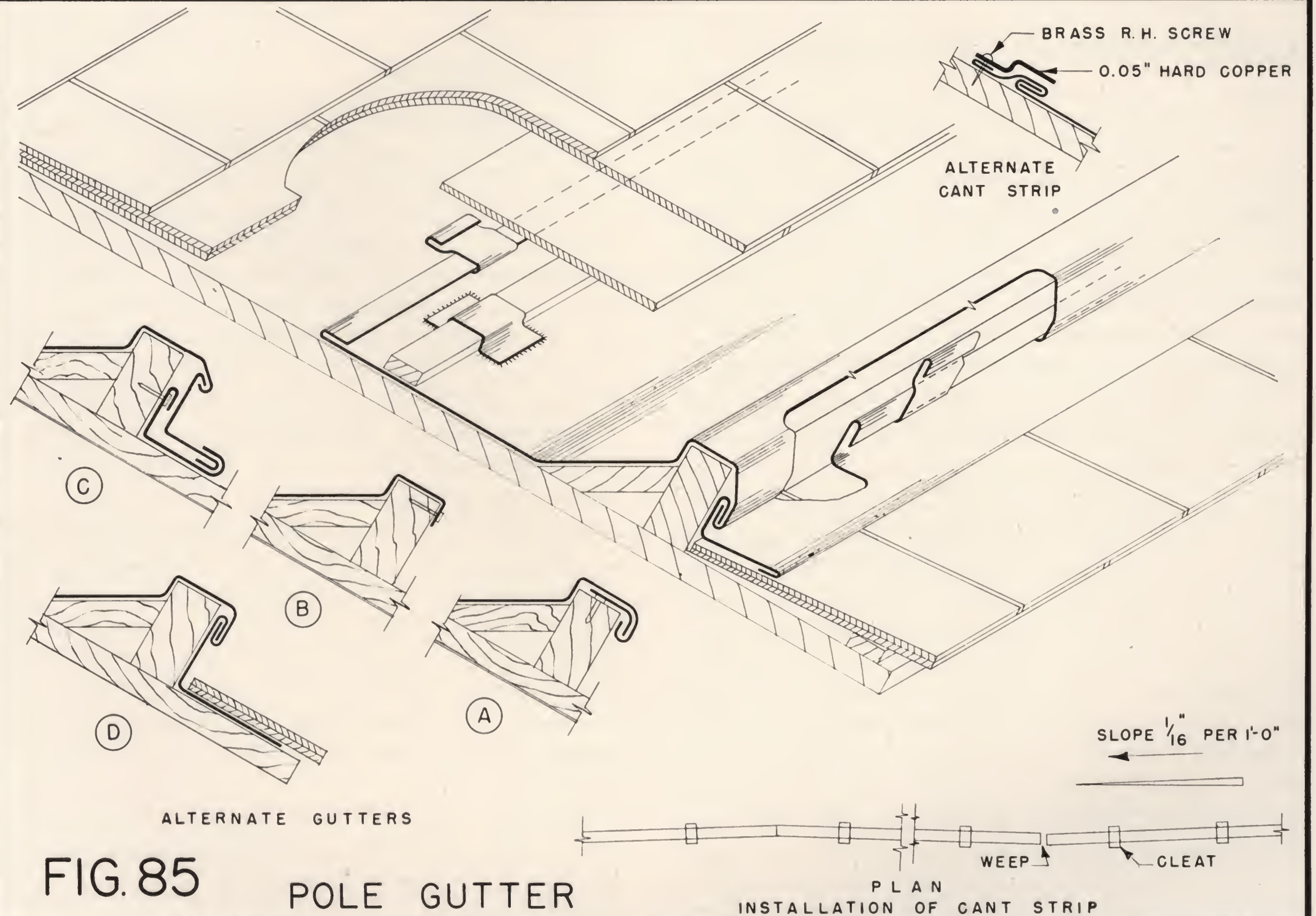


FIG. 85 POLE GUTTER

BUILT-IN GUTTERS

Research by the manufacturers of sheet copper to find out the cause—and correction—of failures in built-in gutter linings has not reached the final stage as this book goes to press. But out of studies that have been going on for a number of years has come the realization that several factors, inseparably conjoined and accessory each to the others, affect the behavior of copper sheet as commonly used in gutter linings. These are: (1) the weight and temper of the copper; (2) the width of the gutter; (3) the design and distribution of expansion joints; (4) the distance between downspouts (fixed end) and expansion joints (loose or moveable end); (5) the side angles; and (6) the strength of transverse joints.

These investigations of metal gutter-linings have demonstrated the fallacy of the common belief that expansion joints alone will obviate the buckling and splitting that cause failure, for they show: that the stresses set up by thermal expansion in the metal lining of a built-in gutter correspond to those in a loaded column; that freedom of movement is absolutely essential to avoid excessive strain; and that tensile stresses do not play an important part.

RIGIDITY DEPENDS ON CROSS SECTION

The design of large metal-lined gutters has developed over the years by trial and error. Until recently no one realized that the formed metal linings act under thermal changes like columns in compression. Laboratory tests of full-scale models show that, within mathematically-determinable limitations, the principles of Columnar Rigidity govern the resistance of these linings to thermal stresses and that their behavior is directly related to: (1) the amount of metal in the section; (2) its hardness or strength; (3) its distribution. Increased rigidity is a resultant of harder temper, heavier gage, narrower surfaces, and steeper sides.

As all unsupported plane surfaces subject to compression, such as copper sheets under thermal expansion stresses, tend to distort by buckling, the obvious ways to minimize such distortion are to make surfaces as small as possible, and to increase resistance of the material by increasing its thickness. Accordingly, the unsupported plane surfaces of gutter-linings should be narrow and short. It is comparatively simple to make such surfaces narrow. But it is not easy to reduce them in length, for gutter length depends on downspout location, which is determined by building design. Therefore the stiffness required for long gutter-linings must be had by adding metal to the cross-section; the longer the run between fixed end and movable end the thicker must the metal be.

GUTTERS ARE TROUGHS—NOT TANKS

The purpose of gutters is to carry the runoff from roofs to the outlet as quickly as possible. To bring this about the designer must fulfill two simple hydraulic requirements: (1) there must be sufficient capacity to hold the runoff; (2) there must be sufficient slope to carry the water away as fast as it runs off the roof surface—outflow must equal inflow.

Unfortunately, because of design limitations, slope and size usually are sacrificed to architectural treatment, and many built-in gutters resemble, and serve as, reservoirs. They are wider and deeper than called for by any formulae for the flow of water in low-gradient open troughs. Such gutters waste metal; and, also, because the thin, unsupported sheets used for linings become overstressed by unnecessary constraint they split or tear, and leaks occur for which the metal—never the design—is blamed. If the parapet wall forming one side of a gutter has to be copper-sheathed, the sheets must be installed with stiffeners and expansion joints, as in **Fig. 36, Plate V,** to serve as a cap flashing for the gutter lining that extends up under it, and is not fastened to it.

DESIGN PROBLEMS

Determination of size and shape of built-in gutters is a complex problem, combining structural design and hydraulics. The unlimited variety of roof slopes and sizes, with all their structural variations, presents to the designer so many problems in the use and placement of the proper materials that hydraulic principles are generally given but perfunctory consideration. Yet their importance can not be over emphasized; for which reason there has been included in this book, on page 113 to 119, data on rain fall, roof runoff and gutter sizes. From a study of the formulae and charts (**Figs. 130** and **131**) on these pages the designer will find that most gutters can safely be smaller than is general practice.

The design of metal-lined gutters involves three things peculiar to all sheet metals. First, is the load, or stress, on the metal that may bring about the buckle that causes failure. Second, is the Yield Strength of the metal, the elastic limit of stress, beyond which failure occurs. Third, is the uneven distribution and concentration of stresses that occur from dents, creases, and similar imperfections in the sheets, or from irregularities in the supporting surfaces.

This latter source of trouble can be circumvented by good workmanship, but the critical loads and stresses that build up under thermal action can be overcome only by careful design.

LININGS MUST BE FREE TO MOVE

Such design includes not only the principles set out above, but also—and of equal importance—mechanical methods that insure the freedom of movement necessary to avoid excessive stresses. The cross seams that join the sheets must be uncleated, for it is useless to design transverse expansion joints and calculate the stiffness necessary to permit cumulative longitudinal movement if the copper lining is so constrained that it cannot move evenly through its whole length. Other recommended methods of providing for free movement, such as loose locks and slip joints, are described in detail on pages 20 and 22.

SIDE ANGLES

Laboratory tests of gutters with sides bent up at various angles indicate that greatest strength (Columnar Rigidity) is developed by rectangular sections. But practical considerations, like the side thrust of ice when a gutter freezes solid, prevent their use in northern latitudes. To be safe we recommend that, while one side of a gutter can be at right angles (90°) to the bottom, the other be sloped at least (60°) from the horizontal.

A GUIDE TO GOOD DESIGN

The problems of copper gutter-linings have not been solved. But steady progress toward their solution is being made in the laboratories of members of this Association.

The need of a guide for architects and builders prompts the following suggestions at this time. It is felt that they are on the safe side.

1. Use cold-rolled copper.
2. Design so that the metal can move freely, using uncleated cross seams, transverse expansion joints, continuous longitudinal slip joints, and smooth, non-adhering undersurfaces.
3. Make gutters compact and narrow, even if by so doing they are overloaded during maximum rainfalls. If the outer edge cannot be set below the roof edge, provide scuppers or auxiliary interior outlets.
4. Make gutter sides as steep as possible. Avoid flat side angles.
5. Increase the weight of the sheet copper as the distance between fixed and moving points increases.
6. On matters of design of built-in gutters that involve usual conditions, consult the technical staffs of the manufacturers of sheet copper.

As a guide only Copper & Brass Research Association offers the following table of Maximum Distances Between Downspouts of Built-In Gutters Lined With Copper for Various Gutter Widths and Weights of Sheets. They are based on side angles of 45° and 60°.

MAXIMUM DISTANCES BETWEEN DOWNSPOUTS OF BUILT-IN COPPER GUTTERS

Width of Gutter Bottom in Inches	Weight of Sheet			
	16 oz.	20 oz.	24 oz.	32 oz.
	Distance Between Downspouts in Feet			
8	30	40	—	—
12	20	35	45	75
16	—	30	35	65
20	—	20	30	55
24	—	—	25	45

NOTE: Proper methods of installation must be used, and the linings must be unrestrained except at the downspout. When copper linings are rigidly attached to the gutter or adjoining construction, the values in the above table no longer apply.

Plates XXIV, XXV and **XXVI** are intended to illustrate the practical application of the principles set forth above. **Plate XXIV, Figs. 86** and **87,** shows a perspective assembly of a built-in gutter, the details of which are shown on **Plate XXV, Figs. 88 to 93. Plate XXVI, Figs. 94, 95, 96** depicts typical built-in gutter installations by diagram and cross-section.

BUILT-IN GUTTERS

Fig. 86 is a perspective drawing of a built-in gutter set in a wood frame. Drawings of the details and sections indicated thereon will found on **Plate XXV, Figs. 88** to **93.**

The lefthand side of the drawing indicates how a standing seam roof is joined to the gutter lining by a ¾″ loose-lock. The ends of the roofing sheets take the place of the copper apron that is used under shingle, slate and tile roofs (as in the rest of the drawing). Obviously, if water is to be kept out of such open seams the outer edge of the gutter must be considerably below (minimum 4″) the inner edge, or roof eave.

The spacing of expansion joints (**Sec. F-F**) and the distance between downspouts (only the outlets are shown in **Fig. 86**) is determined by the gutter width and the weight of copper used, as in the table on page 87. The relative position of expansion joints **B-B** and **E-E** and the two outlets is schematic only. In practice the latter would be placed as near the quarter points of the gutter lengths as possible, and the expansion joint **F-F** would be at the center point (see **Fig. 18,** page 24).

The lining is made of cold-rolled copper sheets shaped to conform to the gutter profile, and wide enough so there will be no longitudinal seams. The sheets do not exceed 8 ft. in length; if the girth exceeds 36″ the transverse seams are not more than 36″ apart.

When of 16- to 24-oz. copper the sheets are joined by ¾″ locked and soldered seams. When of heavier than 24-oz. copper the gutter sheets are joined by 1½″ lapped, riveted and soldered seams.

The Principle of Free Movement is illustrated by the unassembled drawing in **Fig. 87,** where the moving parts of a gutter lining are separated from the fixed parts. Each set is drawn in the same scale as in **Fig. 86.** Thus the effect is that of assembling the lining, or Moving Parts, as 3 separate troughs, and the edges of Fixed Parts, as 5 separate pieces—the Corner Cap; the Apron; the Center Expansion Cap; the End Expansion Cap and Base Flashing; and the Edge Strip. A complete assembly of a gutter lining is shown in **Fig. 94, Plate XXVI.**

The Apron piece, consisting of 8 ft. sheets of 16-oz. copper lapped 4″, extends at least 8″ up under the roofing and, as is shown in **Fig. 90, Plate XXV,** is locked to the inside upper edge of the gutter lining by a ¾″ loose lock.

The gutter lining moves from the outlets toward and away from the expansion joints, this movement being facilitated by the loose-lock joints formed with the Apron and the Edge Strip.

If this Principle of Free Movement is kept in mind while designing and constructing built-in gutters, and the injunctions about gutter widths, side angles, and weight of sheet are observed, there is no reason why built-in gutters should not give long years of leak-proof service.

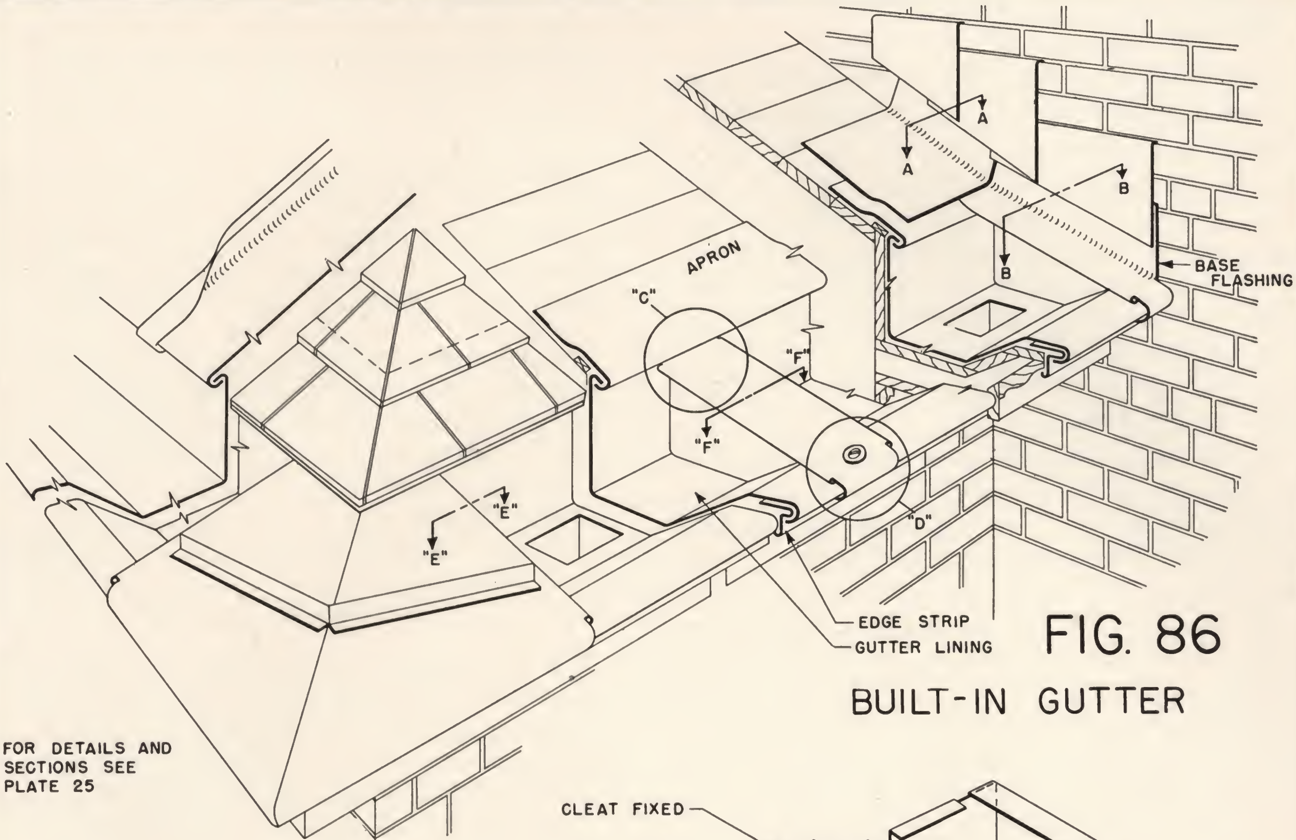
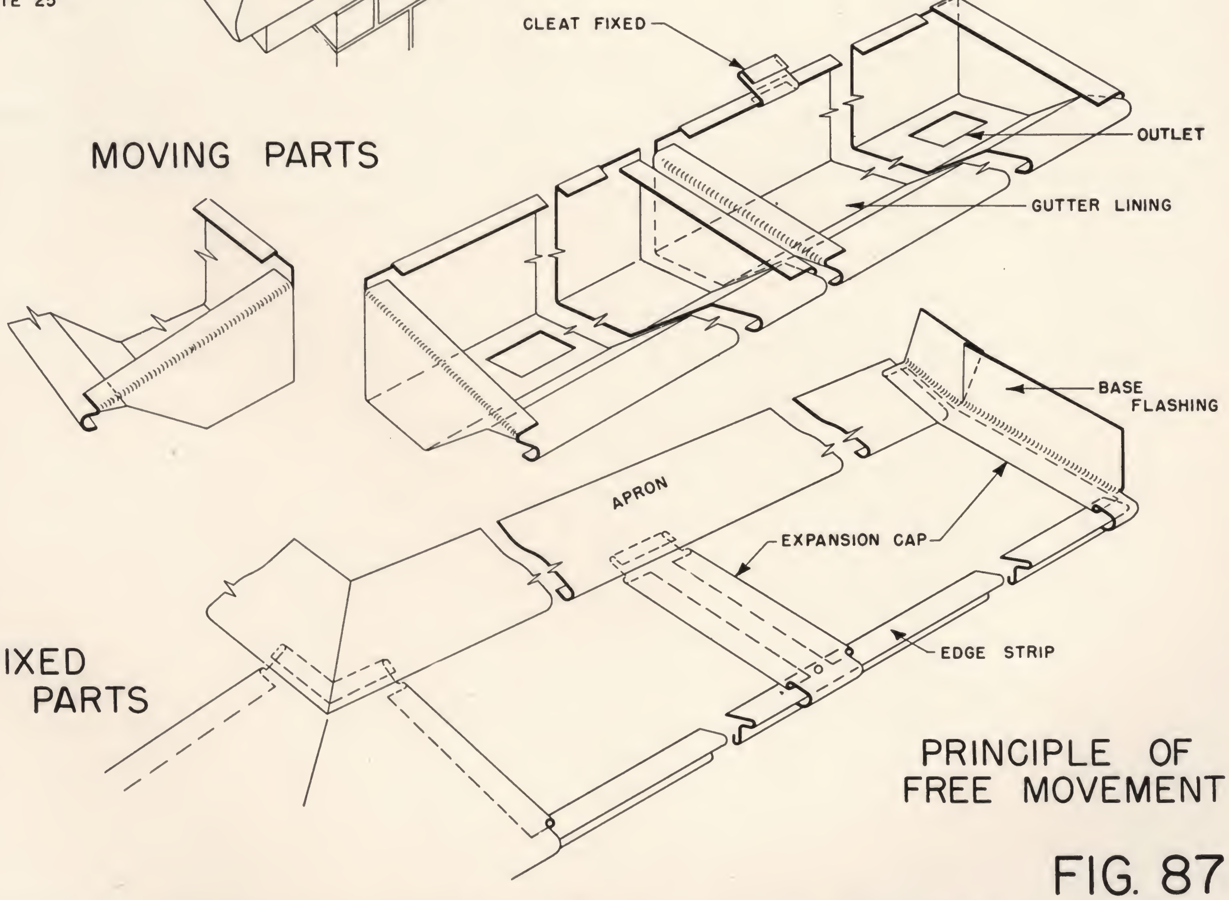


FIG. 86

BUILT-IN GUTTER



PRINCIPLE OF FREE MOVEMENT

FIG. 87

BUILT-IN GUTTERS — CONSTRUCTION DETAILS

Plate XXV contains large-scale drawings of the six details and sections referred to in **Fig. 86, Plate XXIV.**

Section A-A, Fig. 88, shows how the base flashing finishes over the apron and the expansion joint cap where a built-in gutter abuts a wall. As in **Fig. 86** the cap flashing is stepped into the masonry joints and base flashings are woven in as the shingles are laid. A complete detail of this method is shown in **Fig. 64, Plate XV.** The important feature of **Fig. 88** is the manner in which the expansion joint cap extends up the roof as far as the upper edging of the Apron.

Fig. 89—Where the end of a gutter abuts a wall at least 3/4″ free space is provided between the end of the gutter and the masonry, as in **Section B-B.** The expansion cap, it will be noted, is half cap (see **Fig. 93**) and half base flashing.

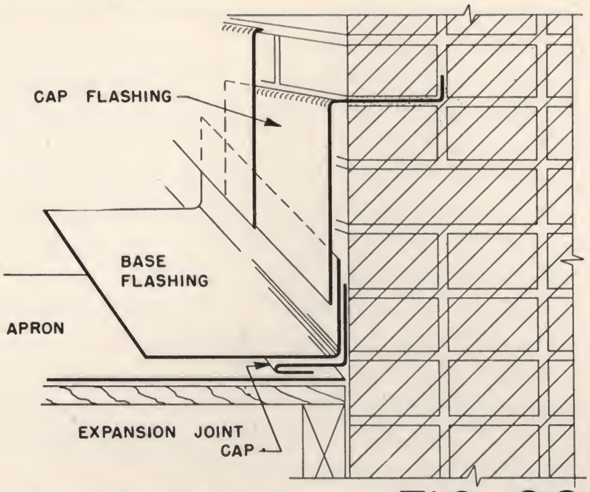
This cap-flashing piece is not nailed or otherwise fastened to the masonry. It is held in place by the lock over the edge strip (see **Fig. 86**), by the roofing that lies upon the apron, and by the cap flashing, the lower edge of which is turned under 1/2″ for stiffness. (This hem edge has been omitted from **Figs. 88** and **89** so as to show the other details more clearly.)

Fig. 90—The back edging of the gutter lining at the roof (Detail **C, Fig. 86**) is bent to form a 3/4″ loose lock, which is held in place with 2″ cleats spaced 36″ on centers. (This cleat is shown in **Fig. 87**). Detail **C** also shows how the gutter lining is notched to make room for the expansion cap and how the end of the latter is slit and bent to form a 3/4″ lock for the apron. Note that this lock is not malleted down against the side of the gutter, but is left extending out from the side as a continuation of the roof slope.

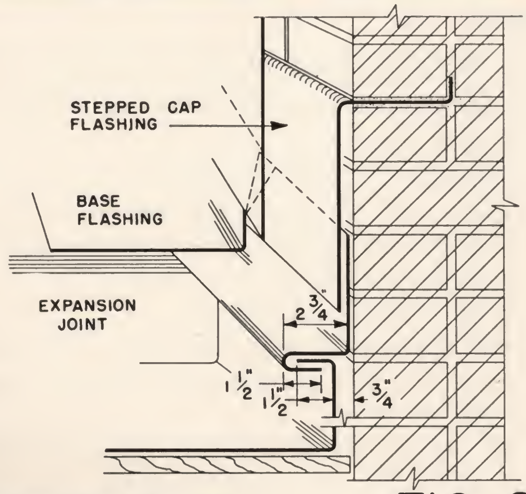
Fig. 91—Along the outer edge of the gutter an edge strip of 24-oz. cold-rolled copper, made of 8′ lengths butted together, is formed (as in Detail **D**) and nailed or screwed to the under framing. The gutter-lining sheets hook over this edge strip to form a 3/4″ loose lock.

Fig. 92—Where the gutter forms the leg of an inside or outside corner, and downspouts are not placed on this corner, it is necessary to provide an expansion joint, as shown in **Section E-E.** The top of the corner cap finishes as the flange of an expansion-joint cap in which the end of the gutter lining moves. The clearance shown, 1″, is considered a maximum for this type of construction. Note that a similar expansion joint is formed on the other end of the corner cap, in **Fig. 86, Plate XXIV.**

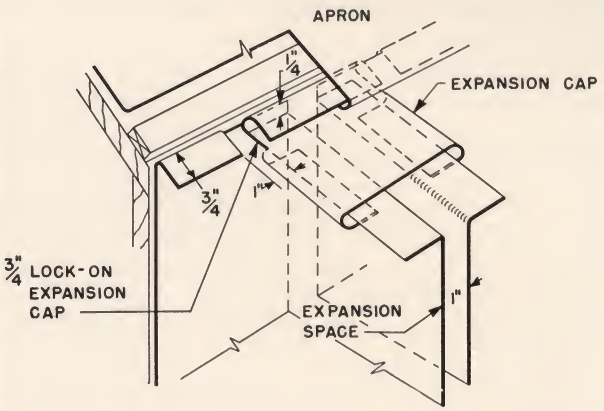
Fig. 93—A typical expansion joint (see **Fig. 17,** page 23) used in breaking up long runs of built-in gutters is shown in **Section F-F.** The end of the gutters are closed with vertical end pieces having their top edges turned to form flanges. Over these is placed an expansion cap wide enough to allow the gutter flanges to move the full distance calculated for local temperature extremes according to the method on page 24. The dimensions given in **Section F-F** are illustrative only of relative widths. The maximum movement of all gutters should be calculated by the method set forth on page 24.



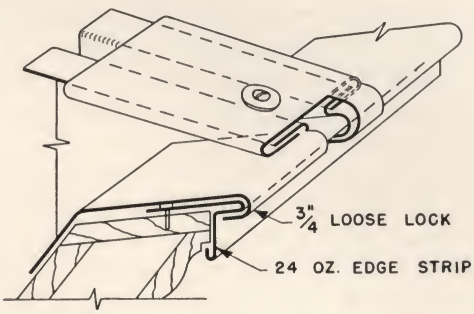
SECTION "A-A" FIG. 88



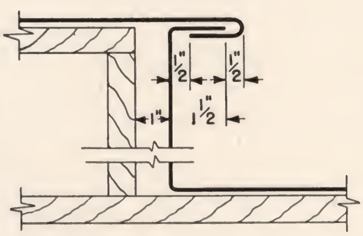
SECTION "B-B" FIG. 89



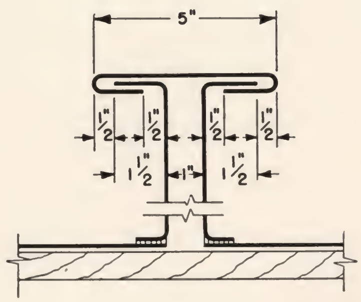
DETAIL "C" FIG. 90



DETAIL "D" FIG. 91



SECTION "E-E" FIG. 92



SECTION "F-F" FIG. 93

BUILT-IN GUTTERS—CONSTRUCTION DETAILS

Fig. 94 shows a perspective diagram of a built-in gutter lining. As has been noted previously in the discussion of built-in gutters:

(1)—There are no longitudinal seams;

(2)—Sheets may be 8′ long, except that if the girth of the gutter exceeds 36″, the cross seams are not more than 36″ apart;

(3)—The cross seams are not cleated;

(4)—The gutter lining is fixed at the downspout and moves throughout its full length to and from the expansion joint;

(5)—The vertical limits of the side angles are—90° to 45°;

(6)—The weight of copper to be used depends on the length, the bottom width, and the side angles;

(7)—The edges are fastened by loose-lock seams to metal strips;

(8)—The outer edge is at least 4″ below the inner edge.

Fig. 95 illustrates a method of installing a copper lining in a larger gutter built behind a stone cornice.

Before placing the copper the surface of the masonry is made smooth and even. (See Section 26 of the Specifications on page 129.)

Along the outer edge of the cornice runs a continuous edge strip (see description of Detail **D, Fig. 91,** on page 91), or a strip of 3/32″-thick brass formed to fit into the reglet and caulked with lead (molten or wool), or held by copper-alloy screws set in lead sleeves in holes spaced not more than 10″, the reglet then being filled with mastic or caulking compound. The edge strip extends over the cornice edge to form the drip shown, and the gutter sheets hook over it to form a ¾″ loose lock.

When the back of the lining finishes against a wall it extends up a minimum of 5″ above the outside edge of the cornice, and is lapped not less than 4″ by a cap flashing let into the wall as shown, or built as a through-wall flashing.

Fig. 96 illustrates a method of installing a large semicircular gutter lining, a type often used when sloping roofs abut parapet walls.

The lining is made of 32-oz. cold-rolled copper sheets, 36″ long, shaped to the gutter profile, and without longitudinal joints. The ends are lapped 1½″, soldered, and riveted with 3/16″ rivets spaced 2″.

The inner edge of the lining is carried up the roof slope at least 4″ vertically above the top of the parapet wall, and is held by 2″ cleats spaced 24″.

The detail shows a method of connecting a copper roof to the gutter lining. A continuous lock strip is soldered, or riveted and soldered, to the lining, and the bottom edges of the roofing sheets are folded under this strip to form a 1″ loose lock. The gutter lining extends a minimum of 6″ up under the roof sheets.

With slate, shingle or tile roof, the lining extends up under the first course at least 6″ and is not punctured by roofing nails. It is hooked by a ½″ loose lock to a separate apron piece 6″ wide that is secured by nailing along the upper edge.

Under the first course of slate is placed a cant strip, formed preferably as shown in **Fig. 85, Plate XXIII.** The **Alternate** shown in **Fig. 54, Plate XI,** can be used provided the copper is 20-oz.

To prevent lifting the lining is held down by copper-alloy screws set as shown in the **Hold Down Detail.** The enlarged hole in the copper permits the sheet to move around the screw shank. The spacing of these depends upon the size of the gutter. Obviously no more should be used than are necessary.

At the parapet the lining is loose-locked to a through-wall flashing under the coping. As this joint cannot be soldered or malleted tight provision against overflow must be made. Scuppers and inside auxiliary overflow outlets can be used, but, in view of the size of these gutters, electric heating coils at each outlet would be most satisfactory and would not add appreciably to the cost.

No matter what mechanical provisions are made there must be periodic inspections of any gutters of this size to remove debris and rubbish.

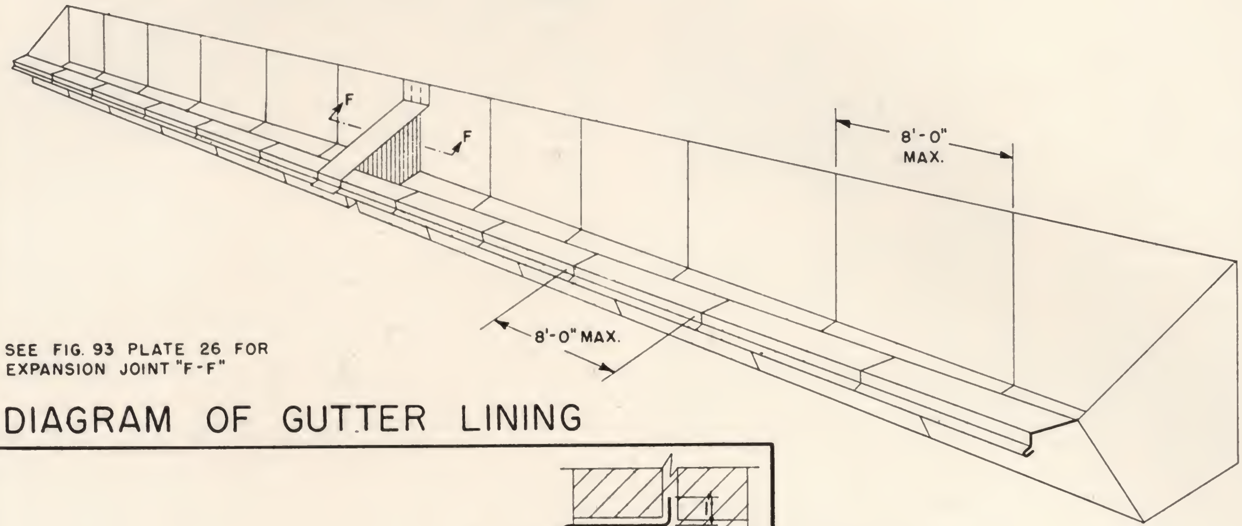


DIAGRAM OF GUTTER LINING

FIG. 94

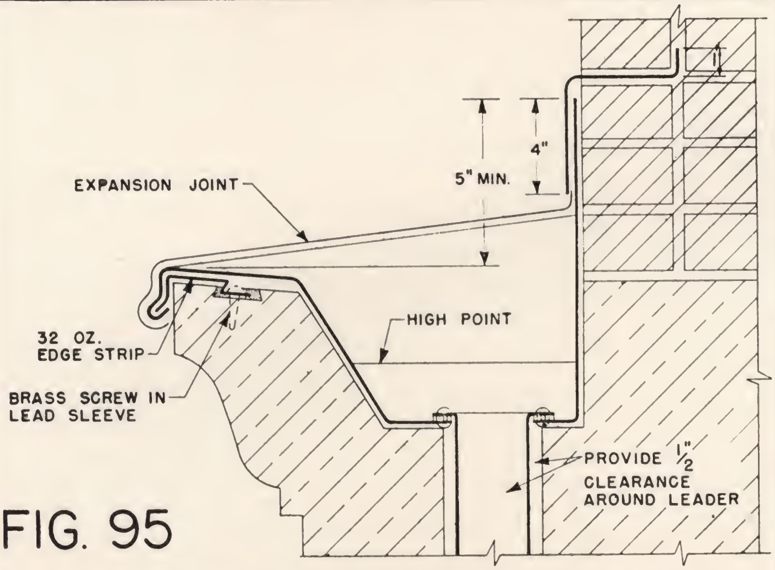
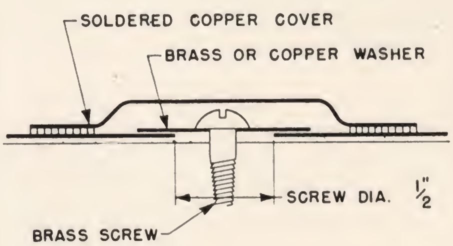
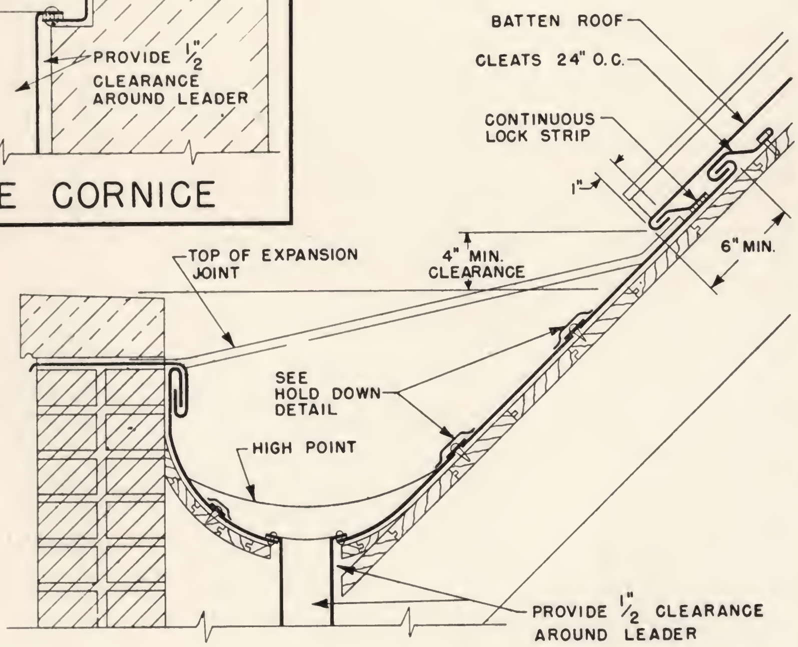


FIG. 95

GUTTER LINING IN STONE CORNICE



HOLD DOWN DETAIL



SEMI-CIRCULAR GUTTER FIG. 96

REGLETS AND CAULKING

When copper flashings are laid over or against concrete or stone they are fastened to the masonry with a watertight joint by a reglet, which is a cut or channel approximately ½" wide at the top and about ¾" wide at the bottom and 1" deep, as shown in **Fig. 97.** The copper, formed as shown, is laid to the bottom of this cut and caulked in place. The surface edge of the reglet should be true, but the interior sides and bottom should be fairly rough to obtain a better bond for caulking. Flaring the sides so the bottom is wider than the top makes the joint more secure.

In concrete work the reglet is best cast when the job is poured by fastening a stock type of copper reglet (of which there are several on the market) to the form with double-head nails, as in **Fig. 97-D.**

Molten lead is recommended for caulking reglets in horizontal surfaces. It flows well into the cut to hold the copper firmly, does not disintegrate, and adjusts itself to temperature changes. On perpendicular surfaces, lead wool is used.

The lead caulking need not be continuous, nor need it be filled in to the very top of the reglet. Very good results are had by driving in lead plugs at intervals—about 12" apart—and filling the intervening space and the top of the reglet with an elastic cement colored to match the masonry.

In England it is standard practice to use, instead of lead plugs, small bits of copper trimmings folded into wedges and hammered in until they spread out and take hold. The reglet is then caulked with mortar or mastic.

No matter what caulking method or material is used, to get the best results the copper sheet must go all the way into the reglet, and must have the ¼" x ⅝" hook detailed in **Fig. 97-C.** This is a small, but very important, detail in flashing buildings faced with stone.

Large sheets are not caulked directly into reglets, as movement from temperature changes will tear them. Auxiliary strips are used in the reglets, as in **Fig. 99,** or to form loose locks for the flashings, as in **Fig. 98.**

The auxiliary strip can be set in the reglet in two ways, shown at **A** and **A-1, Fig. 98.** Some roofers prefer one, some the other. In **A** the reglet filling is protected against weather by the copper sheet. In **A-1** the reglet filling is exposed but is available for inspection or future attention. In either case the lock between the strip and the flashing should be turned out as shown.

The tops of stone cornices are protected from frost action by the extension cover shown in **Fig. 98-B.** A strip of heavy (24-oz.) metal is fastened at the outside edge of the cornice by brass screws, in lead inserts set in a row of holes drilled in the stone far enough back from the face to preclude any possibility of splitting along the line thus formed. The edge of this strip forms a hook (and drip) to which the flashing piece is loose-locked and carried back to lock with the auxiliary strip in the reglet.

If short sheets are used transverse seams are ¾", flat-locked and soldered, with a slip joint filled with white lead or elastic cement every 24 feet (see **Fig. 77, Plate XVIII**). If long sheets are used the transverse joints are best made as standing seams, with the outer ends turned down as in **Fig. 39, Plate VI.**

GUTTERS AND FLASHINGS WITH STONE

Fig. 99 shows a copper gutter lining in a stone or concrete cornice. The flashing is in two pieces, cap and base. The cap flashing is caulked into a reglet or inserted into a masonry joint, and, with the edge turned back on itself ½" for stiffness, is turned down over the base flashing (gutter lining) to lap at least 4". The outside edge of the gutter lining is locked to a copper strip secured in a reglet near the outer edge of the cornice (see **Fig. 98**). An alternate way of fastening the sheet is shown in the lower lefthand detail. The gutter lining is brought around over the stone work and up against the parapet masonry, to be held by the cap flashing. The base flashing extends 3" above the high point of the cornice, so that if the outlet is clogged the water will spill over the cornice edge.

If the width from reglet to wall exceeds 24" the lining is made of small sheets joined by ¾" soldered flat-lock seams as detailed and described for flat-seam roofing in **Plate VII.** The gutter may be graded with neat cement instead of sheathing. The outside of the gutter should be sloped somewhat, as shown, to prevent gutter ice from displacing the corona stone.

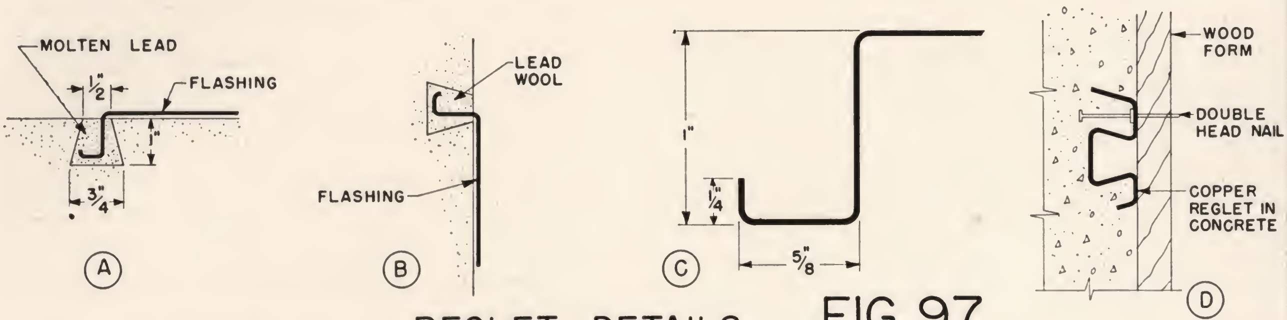
For details of expansion joints and freedom of movement in built-in gutters (of which this is a form), see **Plates XXIV, XXV,** and **XXVI.**

Fig. 100 indicates how the base of a stone balustrade surrounding a balcony or similar projection is flashed with copper. Balconies of this type sometimes are of considerable area and the flooring, which also acts as a gutter, is laid in small sheets flat-locked and soldered (see **Fig. 41, Plate VII**). The grading is done with impregnated sheathing boards or a nailing concrete so that the sheets can be cleated down. The copper is turned up back of cap flashings that are secured in reglets and lap the base copper at least 4". On the outside and at the ends, horizontal reglets are cut in the base course below the balusters, as shown at the right, and caulked with molten lead. On the inside wall the reglet is vertical and caulked with lead wool. Inside drainage usually is provided, connected to the house system.

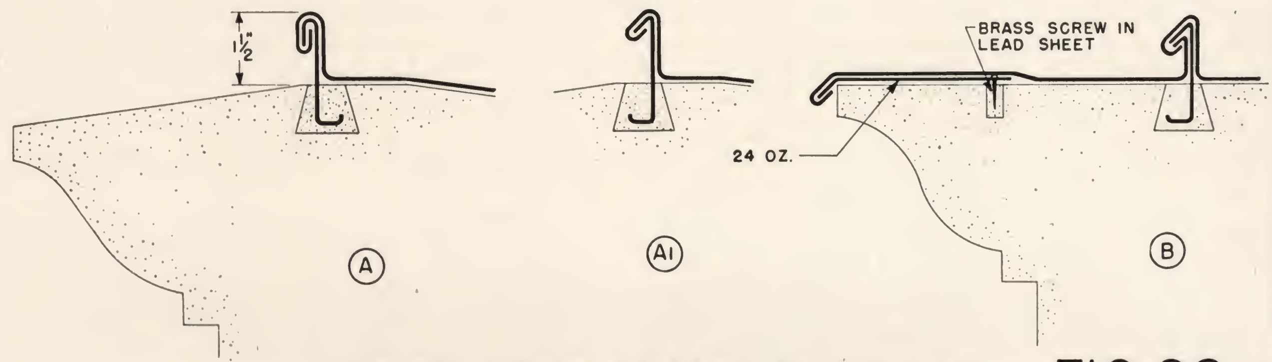
Because of the monumental character and expected longevity of buildings carrying such heavy and ornate masonry embellishments, through flashings are used under these courses.

SCUPPERS

In enclosed gutters such as this, scuppers or overflow drains are essential to provide drainage in case of outlet stoppage. It usually is desirable to have the scuppers concealed, but this, as well as number and location, is a question of design. They must be of sufficient capacity to assure prompt relief, and are usually placed 3" below the top edge of the lowest base flashing. A recommended minimum size of 2" x 6" (12 sq. ins.) is shown in the **Detail of Scupper.** This also shows how the outside flange is made with corner miters brazed. For further details and discussion of scuppers see **Fig. 109, Plate XXIX.**



REGLET DETAILS FIG. 97



LOOSE LOCK SEAMS AT REGLET FIG. 98

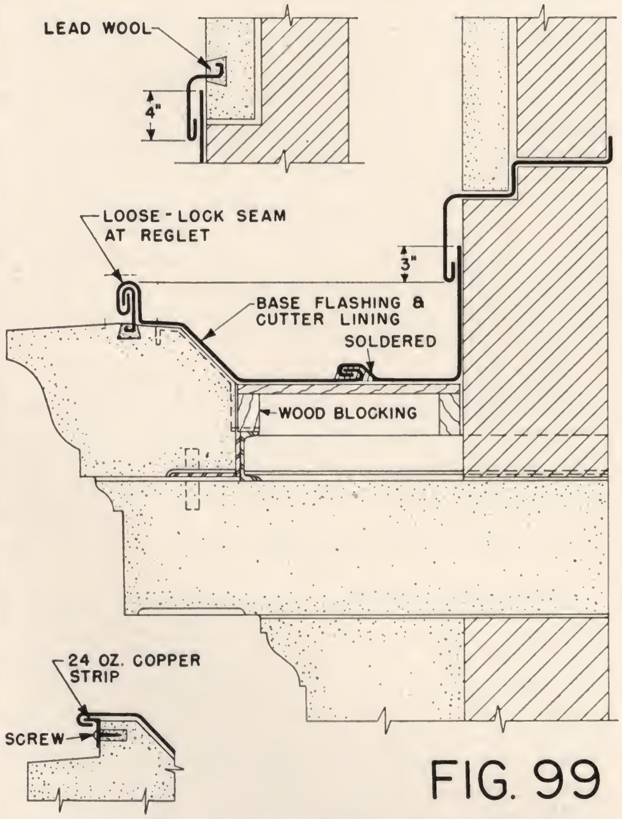
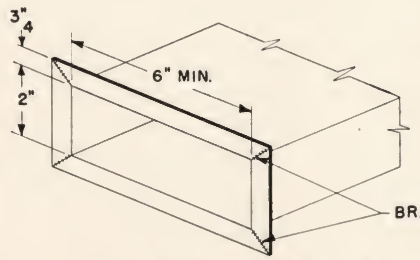


FIG. 99

STONE CORNICE & GUTTER



DETAIL OF SCUPPER

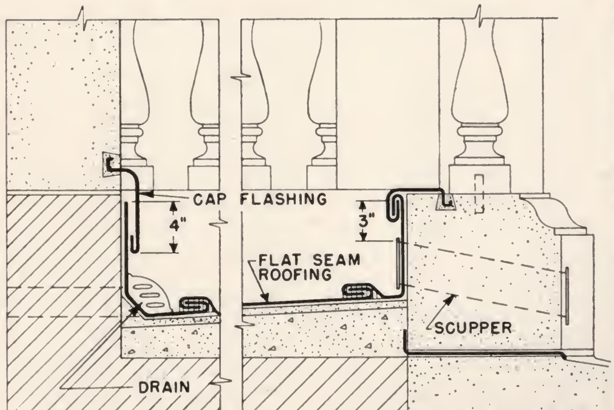


FIG. 100

STONE BALUSTRADE & BALCONY

OUTLETS FOR GUTTERS

Gutter outlets are very important. These connections between gutters and leaders must be designed and built to accelerate the velocity of the water as it passes from horizontal gutter flow into vertical leader flow, and so to maintain the rate of flow.

The tremendous acceleration of velocity as the water plummets down the leader creates a vacuum and air is sucked in to fill it, because the water in the gutter simply cannot get around the corner fast enough. This is why drop outlets from the bottoms of shallow pans never run full. A good example of this hydraulic phenomenon is seen whenever a bathtub is drained. A full one empties almost as quickly as one only part full. This is so because the weight of the water immediately around the outlet keeps it full at the beginning and no air enters. As the water level drops the water remote from the outlet cannot enter it as fast as the water in it is dropping. So the familiar whirlpool forms, the airhole in the center being at first a mere thread. This vortex enlarges as the water level continues to fall, and the rate of flow decreases until only a thin film lines the outlet pipe.

As gutters are intended to handle flash storms with their intense, though short, rainfalls, and as the ratio between gutter depth and leader diameter is seldom 10:1 (about what it is in a bathtub), it is obvious that unless some easement is made between horizontal and vertical flow all the water entering a gutter—which might easily amount to 80 times its volume—cannot possibly get into a leader that is more than capable of handling such a flow. Further data on design will be found beginning on page 113.

The problem would be one of hydraulics alone, were it not for practical considerations. Usual practice in designing the roof drainage systems of large buildings is to determine first the size of circular leader required under maximum conditions. An outlet then is used that tapers down to this size, but is larger where it meets the gutter. The entrance to the outlet forms a conical depression in the bottom of the gutter. An elliptical shape at the top of the outlet, with the long diameter in the direction of the gutter length, aids in collecting the flow.

The same principles apply for small drainage systems, the practical requirements for which can, however, be determined empirically.

For instance, with a 6″ semicircular gutter, the outlet should be 6″ in the long dimension but need have a short diameter of only 4″. For semicircular gutters of other widths, the outlets should have the same proportions. In rectangular gutters 6″ wide the outlets should be about 2″ less in width than the gutter and about the same length as the gutter width. Such outlets are tapered down to the size of the leader.

Another important detail in outlet construction is the loose connection between gutter and leader, so that when the building moves—and all structures distort under temperature changes—it can do so without over-stressing the connection between gutter and leader. This open joint also serves as an air inlet below the gutter, thus helping to prevent the formation of a vacuum in the leader (see page 115).

The connection is generally made with sleeves and tubes, unsoldered because if an overflow occurs it happens outside the building and does little or no damage. But there are installations, as when inside leaders are used to drain level roof pans, where leakage would cause serious trouble. In such cases (of which **Fig. 105** furnishes one example) the construction takes the form of an accordion or bellows (see **Figs. 108** and **110, Plate XXIX**) that will adjust itself to movement without tearing.

Fig. 101 illustrates the outlet for a formed gutter, the general construction of which is the same as is shown in **Fig. 84, Plate XXIII**. The outlet tube is soldered to the gutter, and the leader slipped over it. If wood molding is used under the gutter it should be flashed with copper as shown.

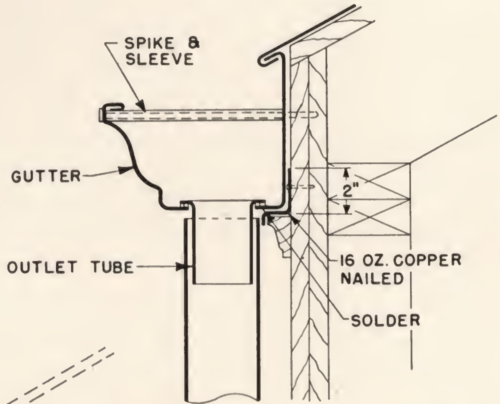
In **Fig. 102** is shown a box gutter typical of the architectural style that calls for a substantial wood cornice. The gutter is framed on the outriggers to which the cornice is hung. Here the outlet tube extends down into the leader well below the soffit, and the leader is carried up inside the cornice to the gutter bottom. If a break occurs at the outlet the overflow will run down the outside of the leader through the cornice, and the appearance of water (or ice) will serve immediate notice of failure.

In **Fig. 103** appears a half-round gutter, of stock or special design, hung from strap hangers which enclose, but do not engage it, so that it is free to move longitudinally. The outlet tube sets inside of, and is not connected to, the leader. In this type of installation the tube is made enough smaller than the leader to permit thermal movement in the gutter, which, contrary to standard practice for other types of gutters, is not fastened at the outlet.

The larger the gutters the more carefully must the designer follow the hydraulic principles set out above and on page 116. The outlet, with its abrupt change from large horizontal opening (low velocity) to small vertical cross-section (high velocity) becomes a determining factor in built-in gutter design. **Fig. 104** shows how outlets are flared to form easement curves, and how such outlet pieces are set. The outlet is really two pieces, one brazed to the gutter bottom and tapering down to the tube, and the other, ¼″ larger all around, brazed or soldered to the outlet tube and flared up and flanged out under the gutter lining. The ratio of depth to width shown is the recommended minimum. Actually for gutters over 10″ wide the formula on page 119 should be used.

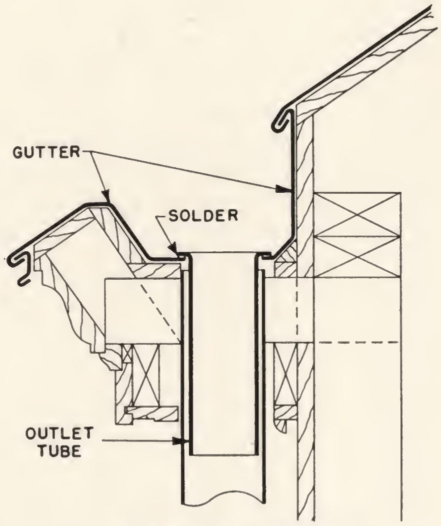
Fig. 105 shows how a horizontal outlet tube, leading to an inside leader, is brazed and riveted to a large semicircular gutter lining of heavy copper. This same construction can be used, of course, with large gutters having other cross-sections. The outlet tube does not have to taper (although it might very well do so, hydraulically) because there is no appreciable increase in velocity as the water enters the outlet tube.

Fig. 106 illustrates how an extra sleeve is used to protect the connection between gutter and outlet tube. The tube is fastened to the leader and carried up and flanged out against the bottom of the gutter lining. The lining is cut to receive the sleeve, which is soldered to it and extends down in to the outlet tube about 6″. This is a good device where temporary outlets must be installed to protect the interior of the building, for the sleeves can be quickly placed and connected to any temporary system, and made a part of the permanent drainage system later



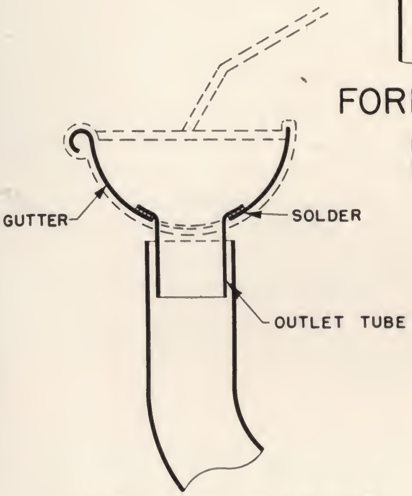
FORMED GUTTER

FIG. 101



BOX GUTTER

FIG. 102



HANGING GUTTER

FIG. 103

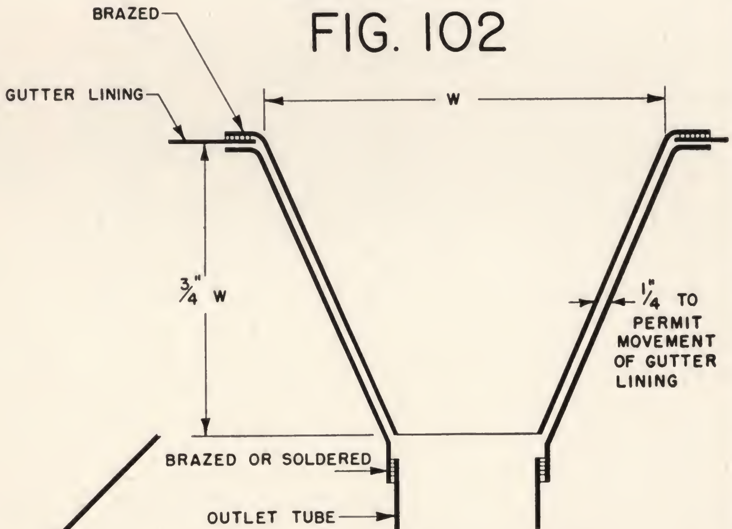
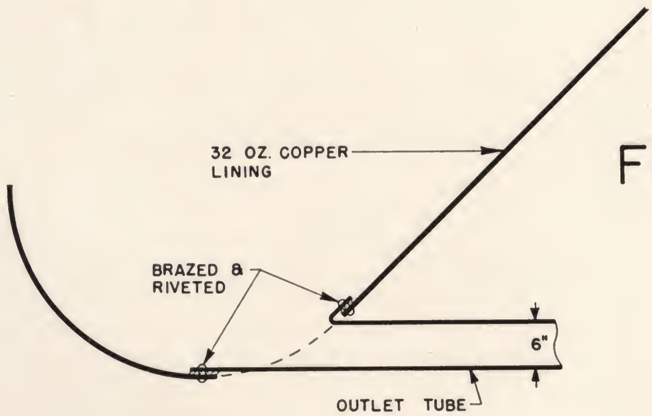


FIG. 105 LARGE BUILT-IN GUTTER LINING



SEMI-CIRCULAR GUTTER LINING

FIG. 104

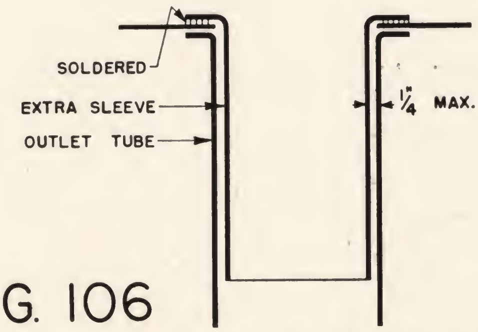


FIG. 106

EXTRA SLEEVE FOR GUTTER LINING

OUTLETS IN FLAT ROOFS

Fig. 107 shows a loose, but watertight, connection between a composition roof and an inside leader. A copper pan (usually square) is formed with a folded-over stiff flange that extends out on the roof far enough (at least 4″) to assure a well-mopped joint with the plies of roofing felt, the upper two of which are placed above the metal. (See also **Fig. 74, Plate XVII.**) The top of the flange is made high enough to act as a gravel stop.

In the detail shown the pan is depressed and shaped to receive the cast bronze strainer (a stock type), and the outlet tube consists of two pieces, a frustrum of a cone and a cylinder, joined by soldered lap seams. Often the pan is level and the tube is a cylinder in which a smaller strainer is set, the tines or prongs being sprung into place. In either case the copper tube fits loosely in the drain pipe with an open space all around, so that, if the pan leaks, water running down the outside of the tube will enter the drain pipe. This is shown as C. I., with bell at top—a good form of construction. Standard G. I. steel pipe is also used, the tube fitting loosely into a nipple.

Note that in this construction the tube is set from the roof down into the drain, as compared with **Fig. 108,** where the tube is first fastened to the drain and then inserted up into the pan.

Fig. 108 shows another method of constructing a connection between a flat roof outlet and an inside leader. The tube is made of heavy copper (at least 24-oz.), with accordion pleats like a bellows to compensate for uneven movement between roof slab and drain pipe, to which, in this case, the outlet tube is secured by a brass ferrule, as detailed in **Fig. 110.** This connection is made by the plumber in the shop, and the tube, unflanged, is pushed up through the roof opening as the top length of drain pipe is set in place. Then the sheet-metal contractor trims, reams and solders the tube to the roof pan.

The roof pan is made as a flat piece that extends out on the roof to engage the plies of roofing felt as described for **Fig. 107.** Near the outside edge of the flashing flange a crimp is tack-soldered. In the righthand example it should be high enough to retain the gravel or slag, and on the lefthand side it should be high enough to finish flush with the top of the tile. The opening into the tube is, of course, protected by a copper (copper-alloy) strainer.

SCUPPERS AND AUXILIARY DRAINS

One important point of roof-drainage design often neglected, or omitted because of initial cost, is provision for overflow from flash rains or clogged outlets. Scuppers and auxiliary drains are used for this purpose.

Scuppers are probably less expensive, and, because they discharge roof water to the outside, always thus give notice of trouble. However, their use is frowned on by architects who object to water stains on light-colored masonry. Usually they are holes or slots through enclosing walls or balustrades.

For these reasons auxiliary drains set above the roof level and connected to the drainage system are preferred by many designers.

Many buildings have flat roofs enclosed by parapet walls and drained by inside leaders. When the outlet becomes clogged water collects on the roof, not only causing overload, but working its way above flashings and into the building. If there is even a remote possibility that clogged leaders can flood a roof area it is essential that scuppers or overflow drains be provided. These should be designed to preclude the possibility of clogging and should be unobstructed by screens, etc.

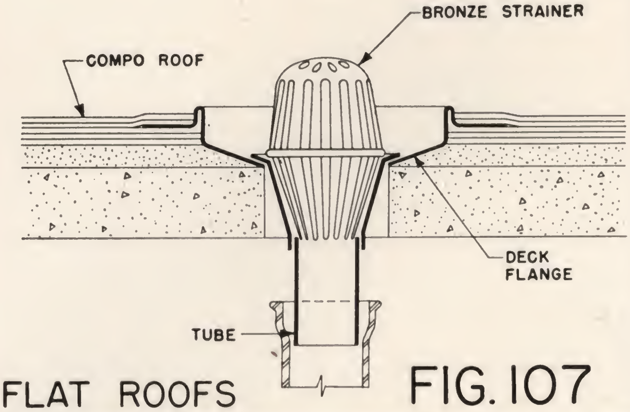
Fig. 109 shows a section through a scupper built as an integral part of a roof drain that abuts a parapet wall. It should be placed so that the top is at least 3″ below the top of the lowest base flashing. Pipes sometimes are inserted in scuppers, projecting 1″ or 2″ beyond the wall to form drips away from the building face. It also is possible, and often architecturally desirable if provision can be made when the walls are erected, to have drains for the scuppers inside the walls. When copper flashings are used the scuppers are completely lined with copper, this being soldered to the base flashing, and the counter flashing worked around the hole, or omitted at these openings.

Scuppers also must be used to drain all balconies or similar small areas enclosed by a balustrade or wall, as in **Fig. 100, Plate XXVII.**

Fig. 110 shows an auxiliary drain. It consists of a secondary outlet beside the main outlet, carried about 3″ above the roof level and flashed with a copper sleeve. This secondary outlet may be drained separately or can be attached to the main drain with a Y-branch. As shown the connection is made with Standard Pipe Size brass pipe. Heavy-wall copper tube is also recommended. This method has the advantage of keeping water from pouring down the face of the building, but can be used only if the base flashings are at least 6″ high, for the auxiliary branch must be carried at least 3″ above the roof and also be 3″ below the tops of all base flashings.

Scuppers and auxiliary drains cost money. They appreciably increase the cost of the roof-drainage system. But this drainage system is, in itself, a small part of the whole building, and its cost is a very small part (perhaps 1/10th of 1%) of the total cost. And repair to damages from one leak can easily cost $1,000 in a $1,000,000 building. So, even if the installation of scuppers, or auxiliary drains, on all enclosed roof areas increased the cost of the drainage system by 50%, such a capital expenditure would be justified.

Moreover the accumulation of excess quantities of water on flat roofs can have serious results, quite apart from water damage. There are two known cases (one quite recently in New York City) where maintenance employees were drowned because their arms and bodies were drawn into large outlets as they reached down in them to clear clogged drains.



FLAT ROOFS FIG. 107

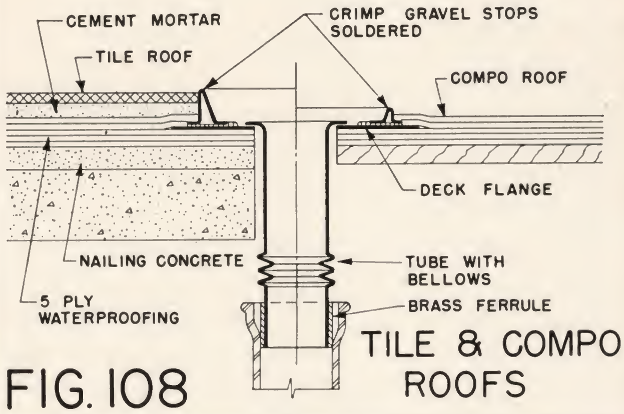


FIG. 108 TILE & COMPO ROOFS

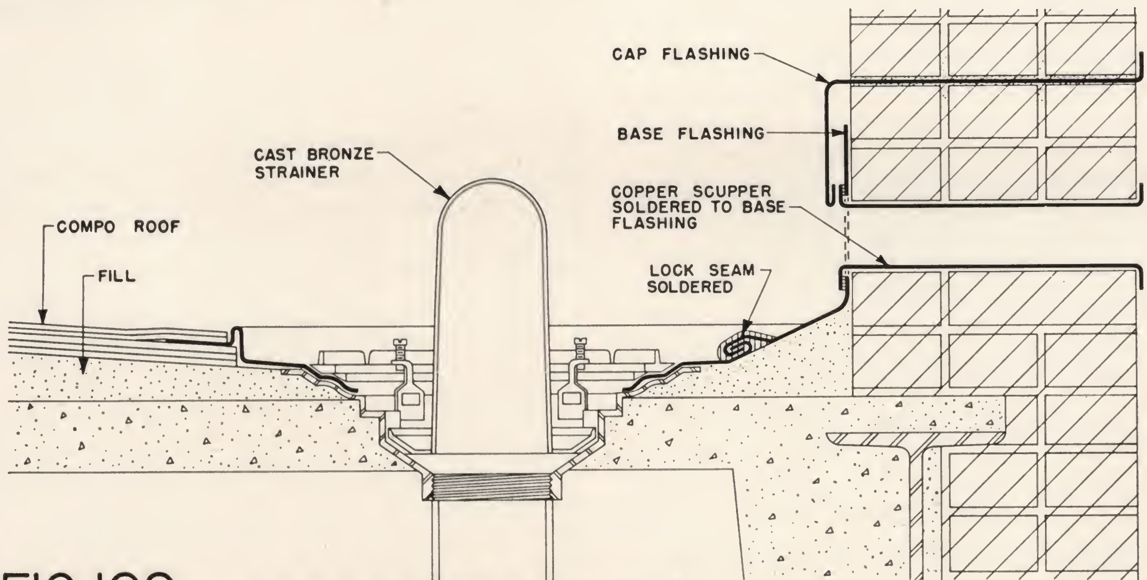
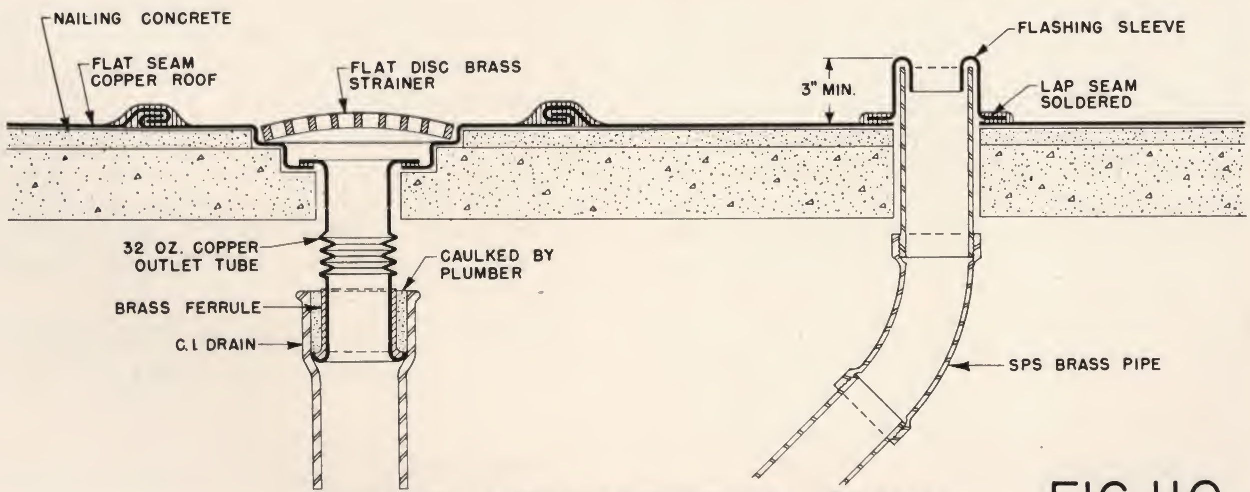


FIG. 109 OUTLET WITH SCUPPER



OUTLET WITH OVERFLOW DRAIN FIG. 110

FLASHINGS OF STRUCTURAL MEMBERS PASSING THROUGH ROOFS

BRICK CHIMNEYS ON SHINGLE OR SLATE

Back of chimneys on sloping roofs ridged saddles, or crickets, are built to shed water and eliminate pockets where snow can collect. In northern latitudes the sides are made quite steep. Sometimes these saddles are large enough to be covered with the roof material, but as a general rule they are flashed as shown in **Figs. 111** and **112.**

Small saddle flashings are made in one piece **(Fig. 112)** with V-shaped filler-pieces locked and soldered at the end openings. Large saddles are flashed in two pieces **(Fig. 111),** with a locked and soldered seam along the ridge.

Against the chimney the metal is turned up as a base flashing, which is cap-flashed as shown, with a minimum lap of 4″. The cap flashings are stepped as necessary to fit the slope of the saddle. The flashing is carried out under the shingles 6″ with the outer edge folded back to form a water dam.

At the corners the upper shingle flashings are reinforced with a piece of copper, soldered to the under side, that fits under the saddle behind the chimney and makes the notches at the corners watertight. The vertical flanges of these pieces are locked and soldered to the base flashing formed by the saddle.

Narrow chimneys on steep roofs can be flashed without saddles (a practice that is not recommended) by extending the copper 4″ beyond the chimney on both sides and folding it over at the corners to form a triangular lap on the roof back of the chimney. The top shingle flashings must extend well up and under this saddle flashing.

When the chimney is at the roof ridge no saddle is needed, each side of the chimney being flashed as described in **Fig. 114.**

Fig. 114 shows how a chimney on the slope of a shingle, slate, or flat tile roof is flashed with copper. When the shingle course over which the flashing at the low end of the chimney is to rest has been laid, this base flashing is set in place. It extends over the shingles 4″ to 6″ with a ½″ hem for stiffness, and is carried up the chimney face high enough so that the cap flashing will lap at least 4″. The copper sheet is long enough to extend beyond the sides of the chimney on the roof as shown and allow the next course of slates to lap it 4″.

The lowest shingle flashing on each side folds around the corner of the chimney and is soldered to the base flashing, the horizontal seam a lap, and the vertical seam a lock. Some sheet-metal men use a vertical lap seam, but most prefer to lock and solder all four corners (see **Fig. 111**). Separate shingle flashings, serving as base flashings up the sides, are inserted with each course of shingles, and are hooked over the top edge of the shingles. Each shingle flashing should lap the one below at least 3″, and the shingles should lap over the copper 4″ along the roof.

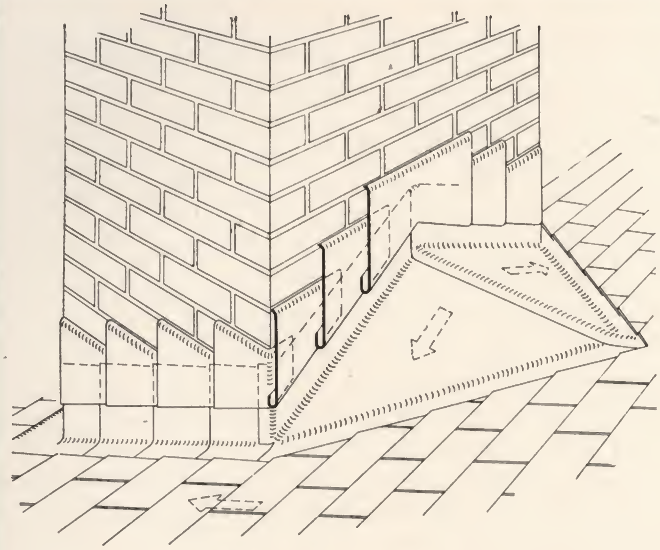
The base and shingle flashings are cap-flashed as shown. Along the lower side where the cap flashing is horizontal, it is continuous, but up the sides it is made of separate pieces, stepped as required by the slope of the roof. The separate pieces have side laps of 3″ and lap the base flashings 4″. The cap flashings are best inserted as the chimney is constructed. If this is not possible, the mason can leave sand joints where the flashings will come. These are easily removed; the flashings are inserted to a depth of at least 2″ into the brickwork and fastened and caulked as described on page 68.

On the low side of the chimney the base and cap flashings can be made as one piece, as indicated in the **Alternate Fig. 114.** The copper is turned into the second brick joint above the sheathing. The lowest shingle flashings are folded around the corners and locked into the lowest cap flashing pieces to form stiff hem edges above the line where the one-piece flashing turns into the masonry joint.

The standard method of flashing a chimney is to extend the copper cap flashing into the wall and turn it up back of the first brick course. Ordinarily this method prevents leakage. Much more efficacious, and hardly more expensive, is the practice of carrying the copper through the masonry and turning it up against the tile flue. If the chimney is a large one, rising some distance above the roof, there is every probability that during prolonged rains water will drive deep into the wall and work its way down to appear as wet spots on ceilings. Such chimneys should be made tight by the flashing shown in **Fig. 113.** Here the copper is carried through the wall as one piece (soldered seams are not indicated) to the flue lining, extended up to the next joint in the lining, carried through to the inside, and turned up.

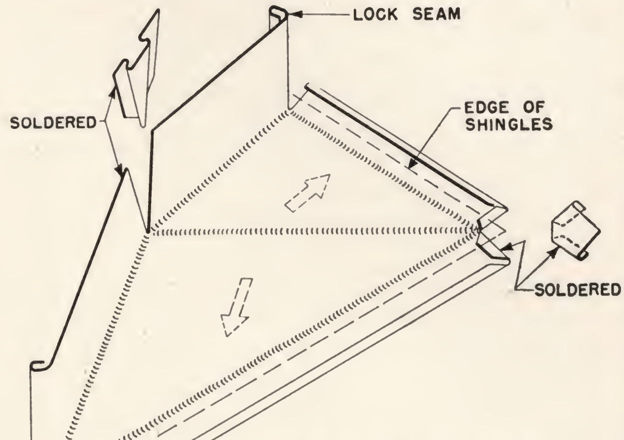
Where the chimney is built of stone, rubble or ashlar, through-wall flashing is even more necessary, because the beds of the stones often slope downward and inward. The flashing is made about the same as for brick masonry, but soft copper is used so that it can be shaped around the uneven stone courses.

Large stone-capped chimneys should have a through flashing at the top as in Detail **H, Fig. 80, Plate XIX.**



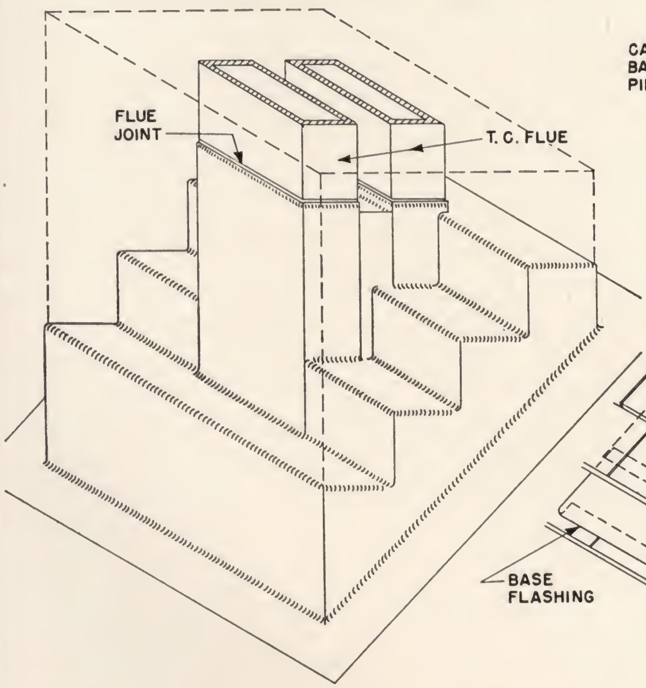
DETAIL OF SADDLE
OR CRICKET
STEPPED CAP FLASHING

FIG. 111



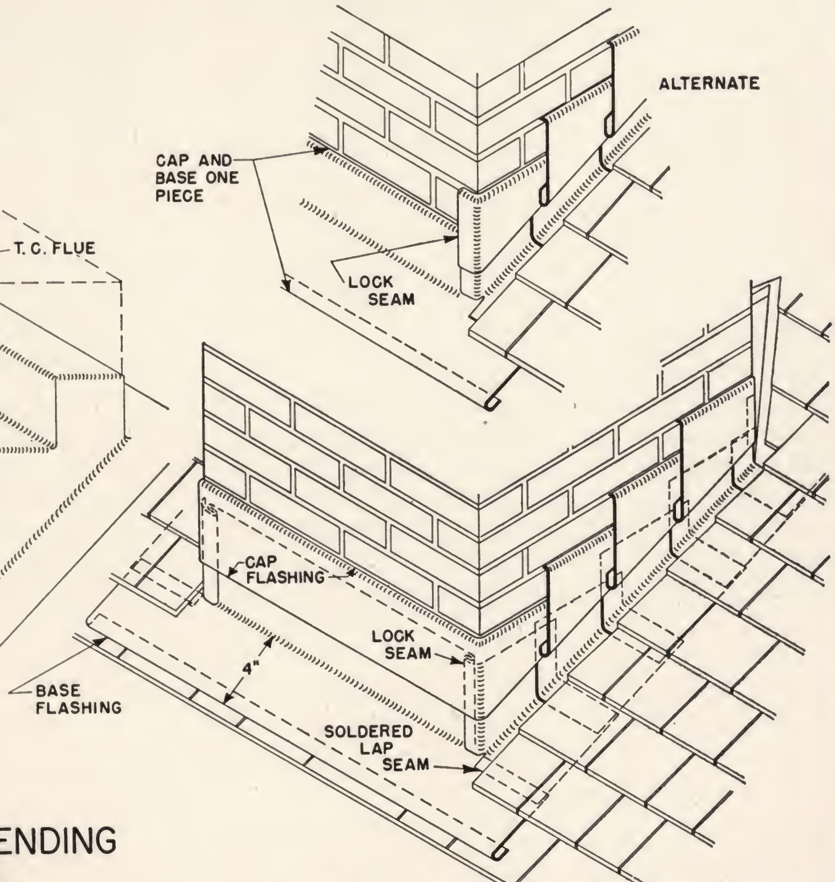
SADDLE MADE
IN ONE PIECE

FIG. 112



THRU FLASHING EXTENDING
INTO T.C. FLUES

FIG. 113



CONTINUOUS CAP
FLASHING AT BASE

FIG. 114

VENTS AND VENTILATORS

Fig. 115 shows a method of flashing an iron or steel vent pipe passing through a shingle roof, and of finishing the pipe with a copper cap. The lower edge of the base flashing laps over the shingles not less than 4", but the sides and top are placed under the shingles and covered about 6". The edges at the sides are folded over ½" to prevent water driving under. The flashing is carried up beyond the butts of the second shingle course above the pipe and nailed, the top edge being folded back to prevent water getting under the roofing. If the flashing is 12" or more wide the lower edge is turned back ½". The sleeve around the pipe is flared at the bottom and soldered to the roof sheet. It extends to the top of the pipe and finishes under a copper cap 6" high and turned down inside the pipe at least 2". As shown it is formed from a single piece of copper, but it can also be made of 3 pieces, as shown in the righthand detail of **Fig. 116.** The vertical flashing should be carried high enough so the cap will lap at least 4". The mass of pipe is large compared with the copper, so galvanic action on the iron will probably be negligible; yet it is good practice to coat the pipe with asphaltum or wrap it with felt.

Fig. 116 indicates the flashing of a vent pipe through a copper roof. Here the flashing finishes under a copper cap as in **Fig. 115.** The flashing around the pipe is flared at the bottom to lap over and be soldered to the roofing sheet, and is carried up the pipe so the cap will lap it at least 4". On steep slopes where it may be difficult to solder close to the upper side of the pipe, the flared flashing can be soldered first to an auxiliary sheet in the shop, and this assembly then dropped over the pipe and soldered to the roofing with lap or lock seams on the job.

This method is interchangeable with the Wrought Iron threaded cap shown in the lefthand detail. The copper sleeve around the vent extends into the notch in the cap not less than 1", and, if the vent pipe is so low that snow can cover it, it is caulked. Before placing the cap the threads are coated with white lead.

While not required for heavy pipes, it is good practice to insulate the iron from the copper with asphalt paint or wrapped felt.

Fig. 117 shows a method of flashing a copper ventilator on a sloping shingle or slate roof. The ventilator is fastened to the flashing by soldered lap seam either before or after it is set in place. When on the roof the flashing should lap the shingles at the bottom at least one course (4" to 6"). At the sides the shingles lap the copper at least 6", and at the top the copper is carried up the roof far enough so the upper part of the sheet is covered by two thicknesses of shingles. The bottom edge of the flashing is folded under for stiffness and the top edge and sides folded over for a water stop. The flashing is fastened to the roof sheathing by long brass woodscrews. To avoid breaking the slates the holes for these should be drilled (not punched), and the screws set through slotted brass washers. Only four screws are indicated in the illustration, but if the ventilator is large more will be required. They should be spaced not more than 12" apart. The holes in the flashing should be slotted, to permit movement, as in **Fig. 50, Plate X.**

Fig. 118 shows the manner of flashing if the ventilator is placed on the ridge of a roof instead of the slope. The method is similar to that described in **Fig. 117,** except that the flashing is entirely outside the shingles and is formed over them. If the ventilator is tall it should be steadied by rods or wires fastened near the top by a brass collar and to the roof by brass screw-eyes or similar devices. The flashings for these consist of pieces of copper extending on to the roof about 8" on each side, and from the butts of the shingles next below up and under the shingles above. A thimble is fitted around the shank, soldered to the sheet, and filled with water-proofing compound; basically this flashing is according to the methods shown in **Figs. 119** and **121, Plate XXXII.**

There are on the market a number of patented vent flashings in copper; and copper ventilators can be had from stock designs complete with flashing pans. Such devices will give satisfactory service if installed in strict accordance with the manufacturer's specification.

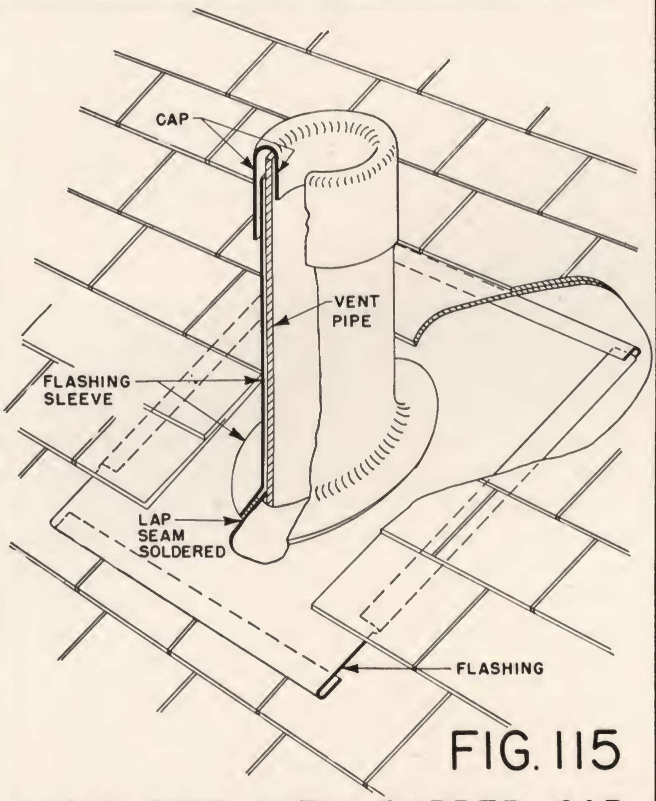
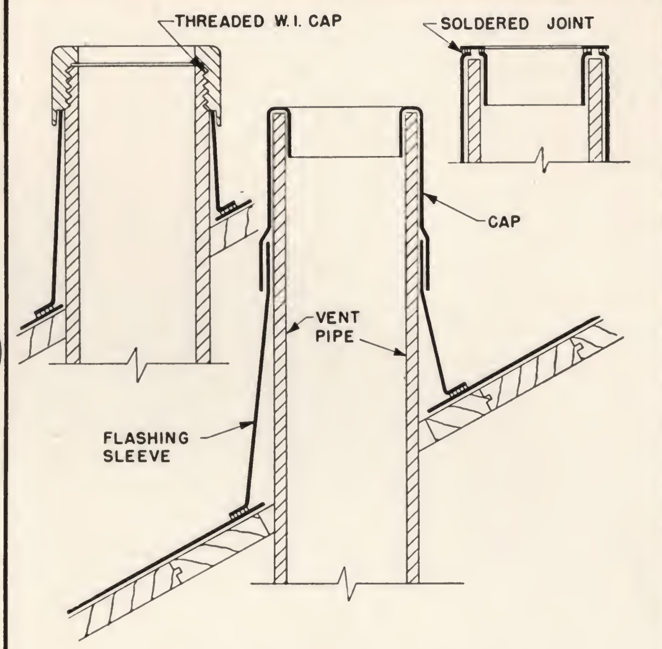


FIG. 115

VENT PIPE WITH COPPER CAP



VENT PIPE FLASHING ON COPPER ROOF

FIG. 116

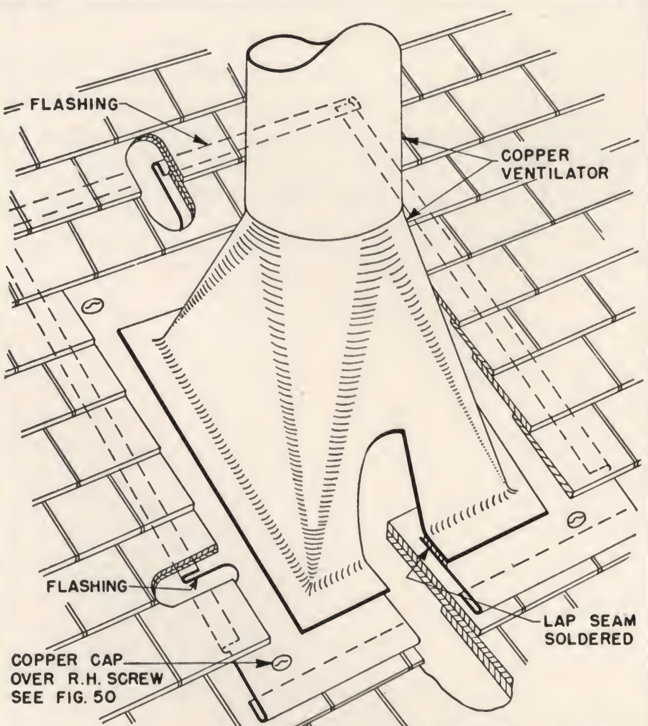


FIG. 117

COPPER VENTILATOR ON SLOPE

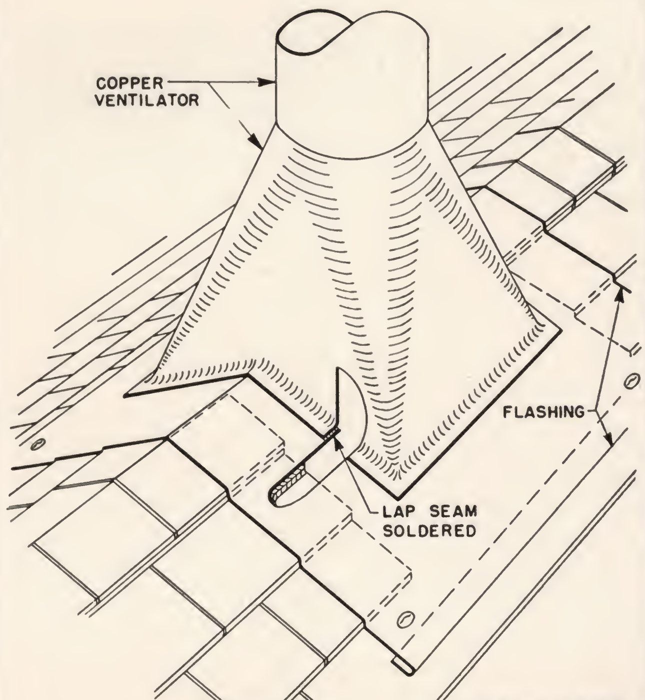


FIG. 118

COPPER VENTILATOR ON RIDGE

DOWELS, RODS AND POLES

Fig. 119 shows methods of making tight the holes in regular flashings necessary to permit the passage of rods, dowels, anchors or similar metal shapes. The details show a dowel cap, and a rod thimble or collar made like a copper cup.

The dowel cap and rod collar are shown round, but may be any shape; they should conform roughly to the contour of the penetrating member.

The regular flashing sheet is cut at the points of penetration and the surplus metal turned up. After this is complete the cap, or cup, is placed.

The dowel cap is a cylindrical piece of copper with the lower edge turned out. This piece is made in the shop just large enough to set over the dowel, and is soldered to the flashing. The coping stone is drilled out large enough to fit snugly over the cap.

The rod collar, or cup, on the other hand, usually is bent around the rod and the ends lapped and soldered. The lower edge (previously turned out) then is soldered to the flashing. On completion the cap is filled with waterproofing compound. The collar must be large enough so the sides will clear the rods, etc., at least ½″.

When an anchor (see upper righthand detail) passes through a termite shield, the opening is made tight by means of the two bolts and copper washer shown. This is a practical and sure way of making such holes impenetrable by termites.

Fig. 120 shows the flashing where a flag pole extends through a roof. The flashing sleeve is turned out on the roofing and joined to the covering in the conventional way described elsewhere. It must be kept away from the pole to allow for vibration, and is flared out and down at the top to cut off drifting snow. A flared hood of 24-oz. copper is placed around the pole, extending down so it will lap the sleeve at least 3″. The lower edge is turned back on itself ½″ for stiffness. This hood is held by a brass split ring 1″ wide set in white lead and bolted. Very tall poles usually are braced by rods secured to a collar several feet up on the pole. The waterproofing of these rods where they penetrate the roof is described in **Fig. 119.**

STEEL STRUTS

Fig. 121.—Often a roof is pierced by steel members, such as struts, holding a platform or similar structure. Great care should be used at these places, not only to make the penetration point water-tight, but to allow for movement of the steel. For this purpose, the detail in **Fig. 121** is recommended. The composition roof is laid as usual, close to the steel, and a copper collar formed around the steel extending out on, and joined to the roof covering. For sizeable units 20-oz. metal is recommended. The collar ends are lapped and soldered and the pan thus formed is filled with pitch or other waterproofing compound. The steel should be heated with a torch for proper adhesion, especially in cold weather. The part extending out on the roof is covered with two layers of fabric, the copper first having been swabbed with pitch. With a tile roof the flashing is laid on top of the regular roof waterproofing. When necessary to make the vertical and horizontal parts of this pan in two pieces the joint between should be a soldered lap seam, as shown.

It sometimes is desirable to have this type of flashing and pitch pocket concealed, in which case the construction is similar except that the flashing collar is placed below the roof level instead of above it. This permits the surface of the roof to finish level. This method is applicable to both built-up and tile roofs.

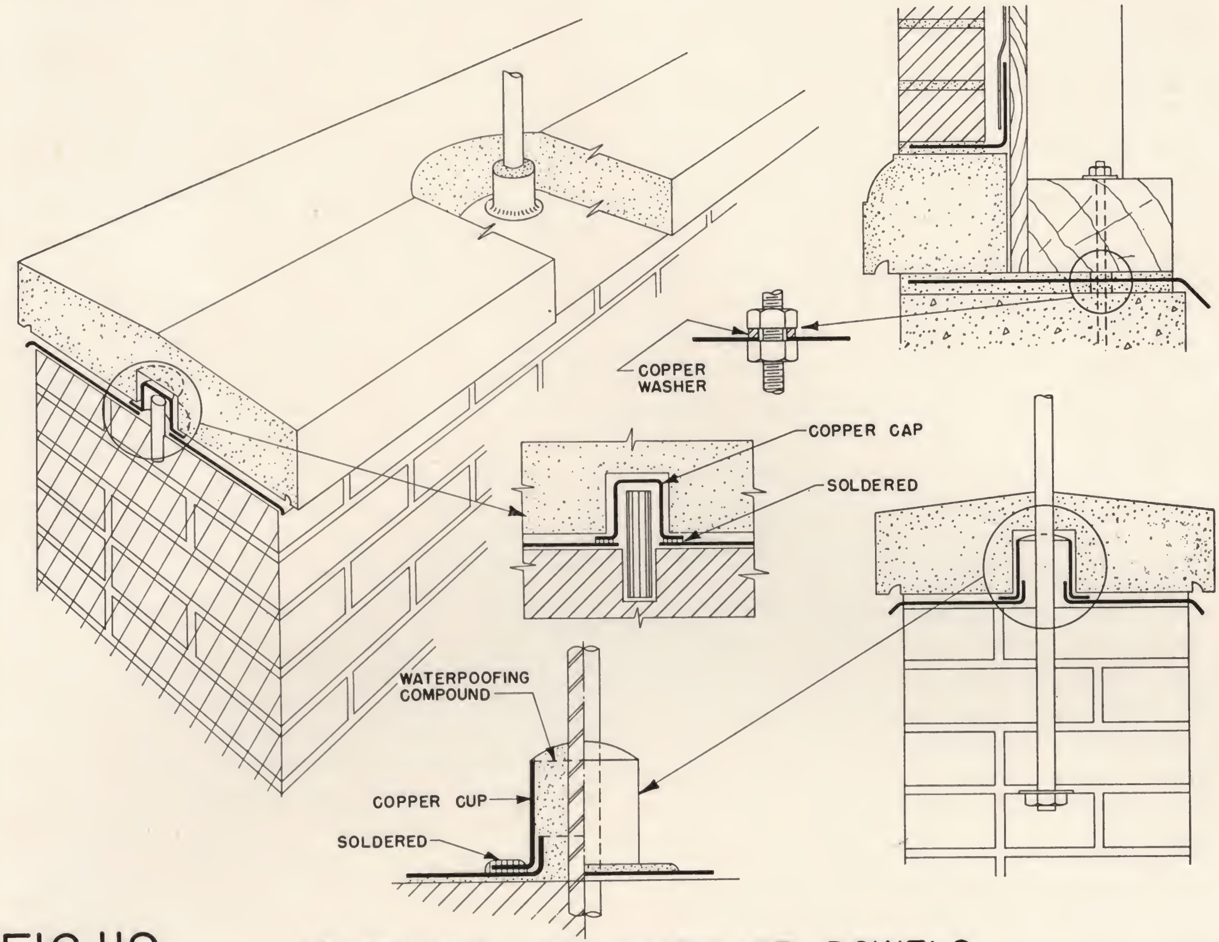


FIG.119 FLASHING FOR RODS OR DOWELS

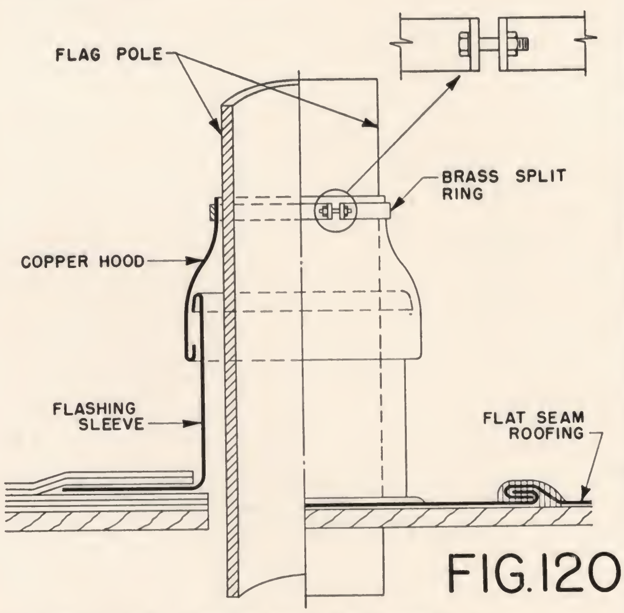
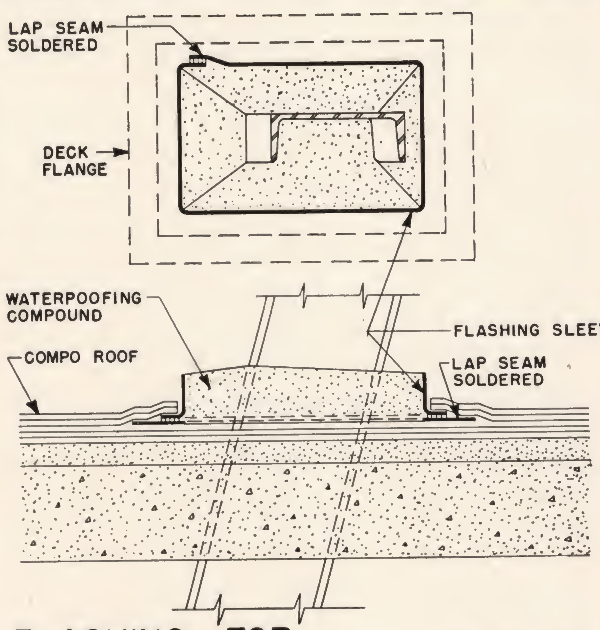


FIG.120

FLASHING FOR FLAGPOLE



FLASHING FOR STEEL STRUT

FIG.121

DORMER WINDOWS

Plate XXXIII shows three methods of roofing and flashing a dormer window on the slope of a shingle or slate roof. **Fig. 122** illustrates a barrel roof covered with flat-seam copper; **Fig. 123** a hip roof covered with standing seam copper; and **Fig. 124** a gable roof covered with flat-seam copper. For all but exceptionally large dormers 16-oz. copper will give satisfactory service.

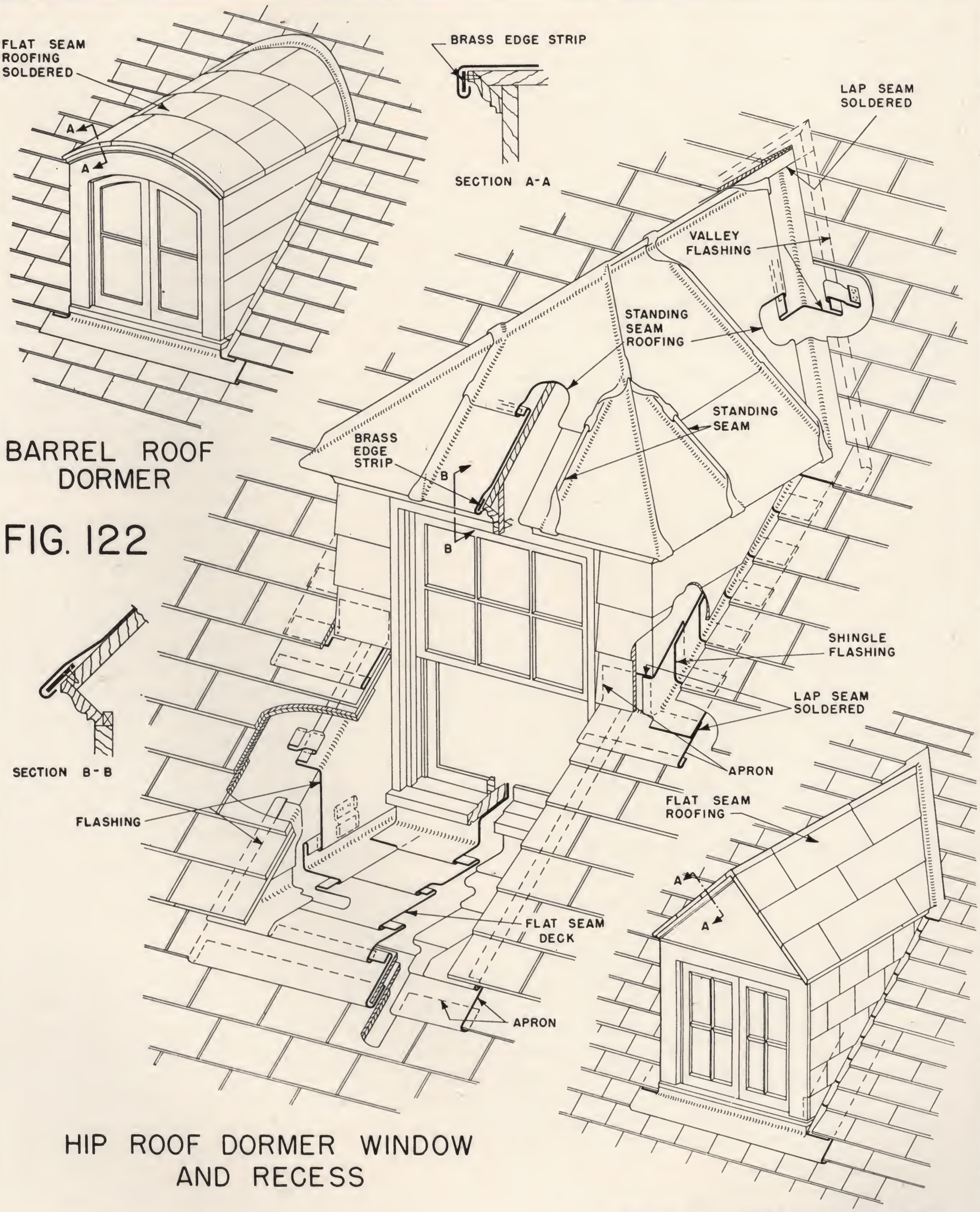
The window in **Fig. 123** is shown with a recess; but if it is not recessed, the construction is the same at top and sides, and the upper apron merely occurs lower down, to be carried continuously across with the shingle flashing under the sill. The roofing is constructed by the standing seam method, using narrow sheets and seams that finish 1″ high. Standing seams are formed at ridge and hips. At the edges the roofing is hooked over brass edge strips previously fastened with brass wood screws to the edge of the sheathing as in **Section B-B.**

The recess deck is covered with small copper sheets laid by the flat-seam method. At the window a flashing strip extends completely through under the sill as in **Fig. 127-C, Plate XXXV,** being locked and soldered to the deck copper on the outside. At the bottom a copper apron locks to the lower edge of the deck and extends down on the shingles at least 4″. It can be finished as shown for the upper apron, or can be hooked over the shingle butts to prevent wind-lifting. The flashings at the sides of the recess extend up from the deck and are carried 2″ under the roof shingles, where they are cleated. At the bottom they are locked to the deck copper which is turned up for this purpose before it is cleated to the side.

The flat-seam method of roofing is used in **Figs. 122** and **124,** the sheets being small (about 16″ x 18″) and joined by ½″ flat-lock soldered seams. Often, to avoid the unsightliness of soldered seams, white lead is used, the nature of the construction being such that there is small possibility of leaks. At the eaves the sheets hook over a vertical edge strip of brass screwed to the face of the molding (**Section A-A**).

Copper open valleys, at the junction of dormer roof and main roof, lock to the roof copper, as indicated in **Fig. 123,** and are cleated far enough up on the main roof sheathing to be lapped at least 4″ and be covered by at least two layers of shingles. Where the valleys cross at the top, the lap seams are soldered.

At the corners, where the roof abuts the vertical face of the dormer, the flashing is done as described in **Fig. 114, Plate XXX.** The apron is placed immediately above the shingles, with bottom edge turned back ½″. It should extend out on the shingles at least 4″ and be nailed 4″ up in back of the siding shingles. The corner shingle flashings are soldered to the apron with lap seams as indicated. The balance of the sides are flashed with single pieces of copper woven into each shingle course. These flashings lap each other 3″ and are carried at least 4″ under the roofing and siding shingles. To avoid puncturing the flashing pan thus formed by nailing the pieces to the sheathing, they are hooked over the top edges of the roof shingles upon which they rest just as in the closed valley flashing shown in **Fig. 59, Plate XIII.**



BARREL ROOF
DORMER

FIG. 122

HIP ROOF DORMER WINDOW
AND RECESS

FIG. 123

GABLE ROOF DORMER

FIG. 124

MISCELLANEOUS FLASHING DETAILS

GRAVEL STOPS

Fig. 125 shows how the edges of roof surfaces covered with gravel or slag on built-up layers of felt are flashed by gravel stops. They are formed of copper, applied along the roof edges and secured at the sides and bottom. There is a crimp above the roof surface to keep the gravel from washing over the edge. The copper extends on the roofing 4″, is well mopped, and is covered with two layers of felt.

The metal never should be laid directly on the roof boards, as the felt will pull away, developing an open joint at the junction of copper and felt. The length of the continuous run is important. For short runs, say of 30′ or less, a continuous strip of 8′ sheets, lapped and soldered, is satisfactory. For longer runs provision must be made for expansion and contraction, such as the loose-lock seam described on page 132, Section 46, of the Specifications.

Detail **A** shows a gravel stop at the edge of a roof laid on a concrete slab. It is secured with brass screws set in the concrete, as discussed on page 27. Holes are drilled about 12″ apart. To prevent water entering the screw holes, copper caps can be soldered over the heads as shown in **Fig. 50, Plate X.**

Instead of forming the flashing sheet itself into the gravel stop, a separate crimp may be soldered on to the flashing as shown in **Fig. 108, Plate XXIX.**

Detail **B** shows a copper dam for dead-level roofs used for water cooling. A heavy copper angle is nailed to the roof sheathing to provide a stiffener for the high crimp that is needed. The dam itself is made of at least 20-oz. copper. The plies of roofing are built up at the edge to cover the 6″ and 4″ legs of metal that are placed in between them. The necessity of making an absolutely watertight joint is apparent.

FLASHINGS FOR WINDOWS AND DOORS

Fig. 126.—When a wood doorway or window pediment is placed against a brick wall, as in Details **A** and **B**, the junction between the pediment and the wall must be flashed. The brick work is built up as the building progresses, but the molded wood doorway is not placed until later. For this reason, and also because of expansion and contraction, a two-piece flashing (cap and base) is used.

The cap flashing is built in as the brick work progresses and each sheet laps outside the next lower sheet at least 3″. It may be cut from one or more sheets, by notching the upper edges and turning them into the brick work. The lower edge is turned back ½″ for stiffness, and the sheet laps the base flashing at least 4″.

Section X-X shows how this is done. The base flashing is hooked over a brass or copper edge strip secured to the wooden cornice with brass wood screws. The cap flashing is secured in the masonry, back of the first brick, and turns down over the base flashing. If the doorway width is such as to require multiple pieces with cross seams, they are made with ½″ flat locks, cleated down. The ridge is finished with a flat-lock seam, as in **Fig. 32, Plate IV.**

A through-wall flashing should be set in the brick work above the course where the topmost flashing piece enters the wall. (See page 78, Location 9).

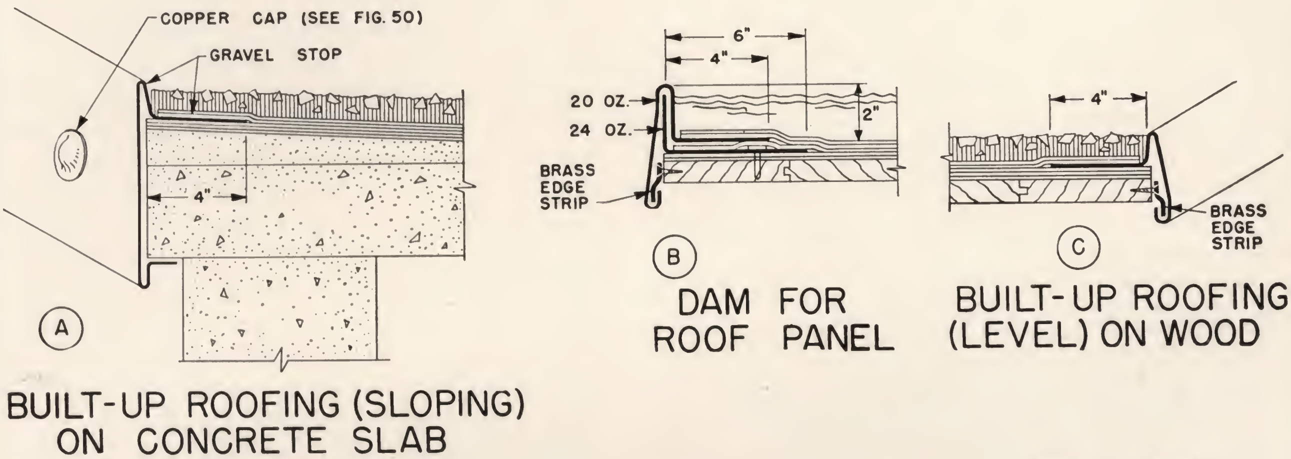
If a concealed flashing is desired, the metal enters the wall at a slot flush with the top of the pediment, after the fashion of the base flashing in **Section Y-Y.**

A wood doorway against a stucco and a shingle wall is shown in Details **C** and **D**. The wood trim will be in place before the stucco or shingles are applied. If the cornice is not wide, and is angular rather than segmental, the flashing may be in a single width instead of cap and base construction. When the doorway has a segmental head, as shown at **C,** only two-piece construction is practicable, the length of the sheets on the wall being determined by the sharpness of curvature of the doorway head. Each sheet should lap outside the next at least 3″.

Section Y-Y shows the construction when top of the doorway is arched. Due to the curve, a vertical edge strip cannot be used, and instead the base flashing is hooked over the bent leg of a copper angle secured in short sections to the edge of the cornice. For a concealed flashing, the base sheet extends across the top of the pediment, and is turned up about 1½″ against the sheathing. The cap flashing consists merely of a copper angle of a length suitable to be formed to the curve, with a vertical leg of 2½″ or 3″ and a horizontal leg of ¾″, set atop the base flashing against the wall. It is held by cleats, about 18″ on centers, previously soldered to the base flashing. Building paper or felt, metal lath, and stucco all lap outside the cap flashing and extend down to just above the roof line. If an exposed flashing is not objectionable, the cap flashing construction can be handled as in **Fig. 72, Plate XVII,** though of course, the curvature of the arch will determine the length of sheets.

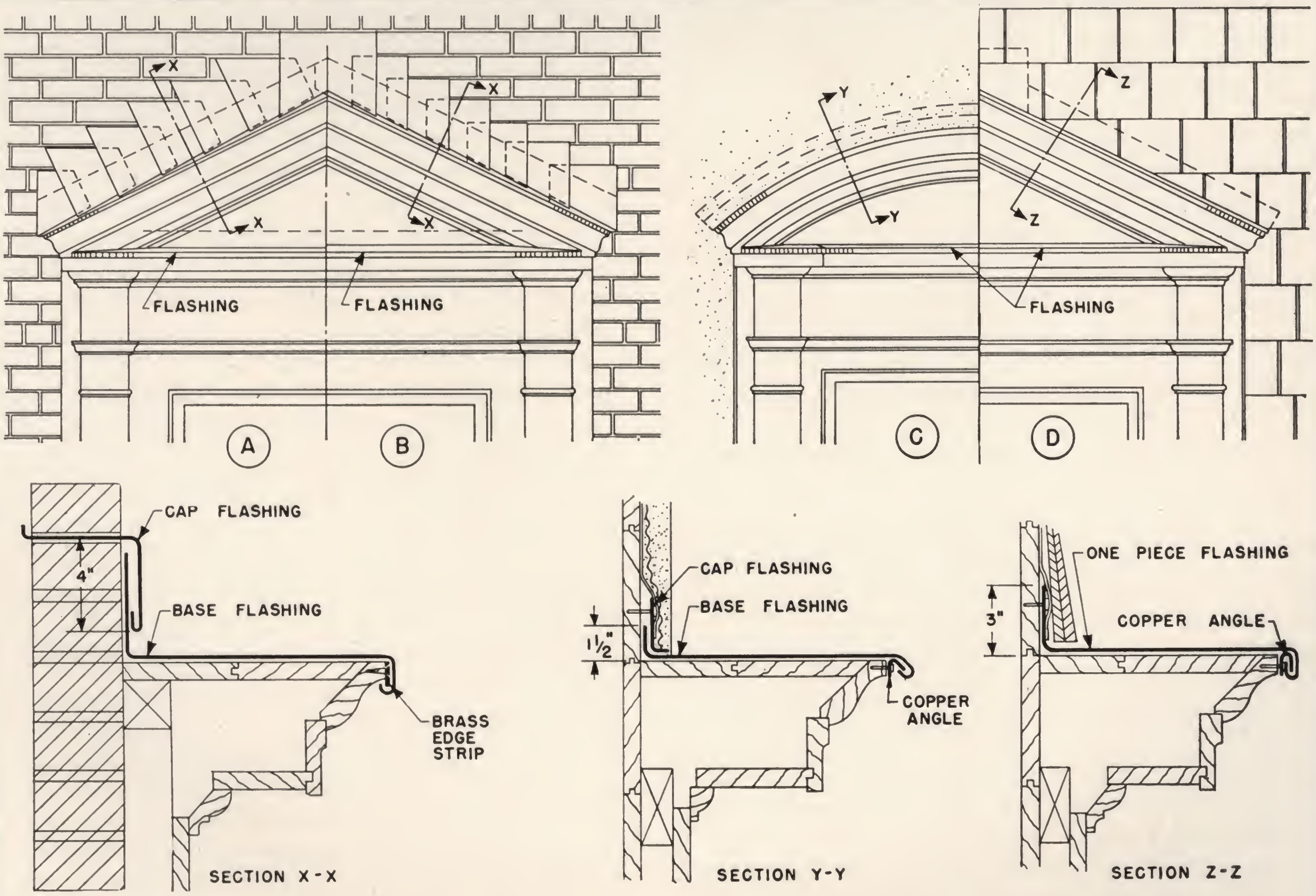
Detail **D** shows construction with a shingle wall when the pediment is sloping. The flashing is in one piece, hooked over an edge strip on the outside and extending up the sheathing back of the shingles 3″. To hold the flashing in place until the shingles are applied, it can be cleated to the sheathing at 2′ intervals by short folds notched in the edge of the sheet to engage the cleats.

The horizontal surface over the door head is flashed with small pieces of copper, lapped, or locked, and soldered. The pan thus formed is turned up into the masonry, or against the sheathing at the back, and is dressed down over the edge of the molding at the front.



GRAVEL STOPS

FIG. 125



FLASHING FOR DOORHEADS

FIG. 126

FLASHINGS FOR WINDOWS AND DOORS (CONTINUED)

In **Fig. 127** are grouped typical flashings for windows and sills in wood construction as commonly used in residences.

Details **A** and **B** show two methods of flashing a wood window head in a stud wall. In **A** the copper strip is folded over the wood drip cap, with the edge turned out at 45° to form a drip. In **B** it is fastened by nailing along the face of the molding, with the bottom edge turned out to form a drip. An alternate method of fastening is by hooking over an edge strip (see **Fig. 79, Plate XVIII**). The edge-strip method is particularly desirable when the trim has considerable projection or when a row of nails would be unsightly. Another way of covering the nail heads is shown in Detail **G.** The flashing is placed after the frame and outside trim have been set, but before shingling. It is carried up at least 3″ and covered by at least two thicknesses of shingles.

If the wall is stucco, the flashing is usually in two parts, as at the top of Detail **E.** The cap flashing extends at least 2″ up in back of the stucco lath, is nailed to the sheathing (or studs) and turned at 90° to form a ground for the stucco. It is formed also over a wood ground placed over the sheathing flush with the stucco, lapping the base flashing as in **Fig. 72, Plate XVII.** The base flashing is hooked over an edge strip, as in **D,** or nailed to the wood member as in **A** and **B.**

Flashing for a window sill is indicated in Detail **C.** It is set after the sheathing and blocking are in place, but before the frame and sill are installed, being nailed to the sill blocking with copper (copper-alloy) nails. It should extend 4″ onto the roof and as far as possible under and up behind the sill. The outside edge should be turned back on itself ½″, and after the shingles are placed, dressed down on them.

Detail **D** illustrates how a window-head cornice is flashed. The copper is in one piece. It is hooked over an edge strip (or can be nailed as described above), and is carried back and up against the sheathing at least 4″, where it is secured by nails through the starting strip for the bottom shingle course.

In Detail **F** is shown a hidden sill flashing. In this case the window is a casement; but it is obvious that the same detail can be used with double-hung frames. The copper extends under and up behind the sill (as in **C**) and finishes between the shingle courses, the outer of which is set in a notch in the under side of the window sill. The vertical lap should not be more than 2″, so that the shingle nails will not penetrate the copper.

Detail **G** is a variant of **A, B** and **C.** While it shows a flashing for a wood water table, the methods of application, except for fastening the lower edge, are interchangeable. The fold-over shown (about ¾″) has two advantages: it conceals the nails: it provides a stiff drip-edge fastening that makes it unnecessary to secure the top edge.

Detail **J** illustrates a way of flashing a door sill that opens onto a canvas-covered roof deck. Leaks occur at this point because no metal is used, the canvas being turned up under the door sill. In a few years the canvas, no matter how impregnated, weakens and tears. In the detail shown the sill is flashed just as in **C** and **F,** and the copper is carried out on the roof 4″ and nailed to the sheathing. Over this, after it has been well covered with whatever is being used to impregnate and fasten it to the deck, the canvas is stretched, turned up under the sill, and secured with copper tacks. The flashing strip is flexible enough to permit some settlement between deck and wall, and the canvas will not separate from the copper if it is well saturated at the time of application.

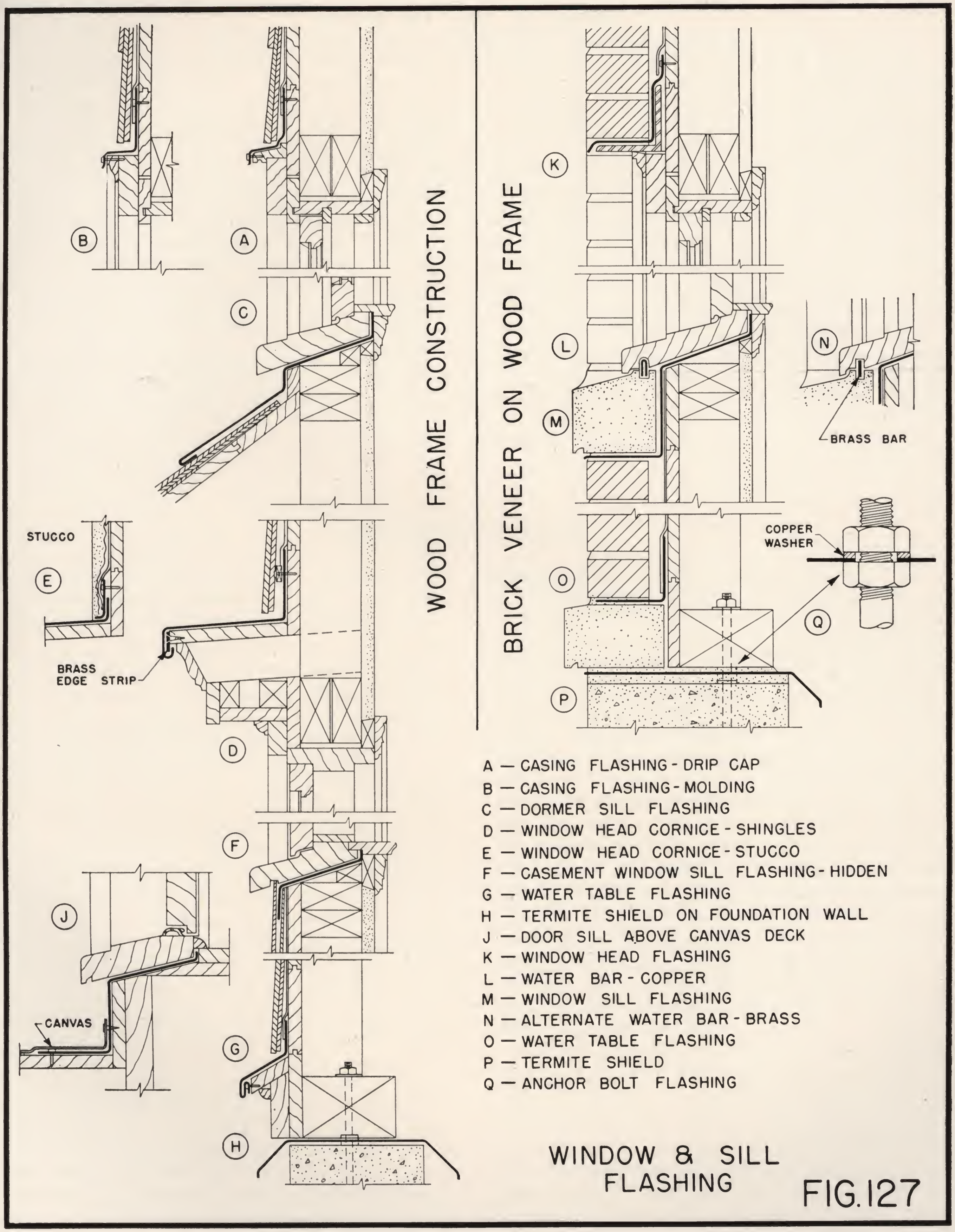
Detail **K** shows a window head, or lintel, flashing in brick veneer construction. The principle of carrying the copper up behind the masonry, and over the steel angle to the inside of the wall has been discussed on page 80. The angle iron should be well covered with asphalt paint to separate copper and steel.

Details **L** and **N** illustrate water bars inserted between a wood and a stone sill as a cutoff to water entering the horizontal joint. The metal strip should be about 2″ wide, formed of a folded strip of 20-oz. copper (as in **L**) or of brass (as in **N**). The water bar is inserted in a slot in the wood sill and a reglet cut in the stone sill. Just before the wood sill is placed, the reglet is filled with pitch or other waterproofing compound.

Detail **M** shows how the flashing of a masonry sill and a wood window frame is done with one piece of copper. This, it will be noted, is a typical through-wall flashing (see **Fig. 81-J, Plate XX**). As the weight of the masonry sill holds it in place no nails are needed, though the nails that secure the apron molding do penetrate and hold it.

In Detail **O** is shown a water-table flashing under the bottom course of the brick veneer. It is carried up against the sheathing at least 4″, and, while it is not necessary to secure it because the weight of the masonry holds it in place, it is often tacked down to permit an even joint with the sheathing paper, which at this line, should be cemented to the copper with asphaltum or mastic.

Note how the building paper is carried down outside of the copper in Details **A, B, D, E, G, K,** and **O.** This is standard practice in good construction. However there is a tendency, in these days of high labor costs, to neglect such small, but important matters. Sometimes the building paper gets behind the copper, thus destroying completely the efficacy of the flashing.



WINDOW & SILL FLASHING

FIG. 127

TERMITE PROTECTION

Until recently the menace of termites has been confined to restricted areas of the United States, chiefly on the West Coast, but now these destructive insects have invaded the East and are to be found in practically every state in the country.

Termites work their way from the earth into the wood sills, joists, studs, and floors of buildings not specially protected against their invasion. They build shelter tubes over the masonry and other impenetrable materials in order to pass under cover to the supporting timbers and other woodwork of a house. There, unseen and often unsuspected, they carry on their destructive work.

More than 95% of the termites are of the "underground" type, which, to live, must maintain their contact with ground moisture through these shelter tubes.

The essential thing in dealing with termites is to cut them off from their contact with ground moisture. This is effective both for houses which they have penetrated (and mostly their work is under cover and will not be evident until a wooden beam which they have devoured fails) and for new and unaffected structures.

Shielding of 16-oz. copper, used as indicated in Details **H, P,** and **Q** (**Plate XXXV**, page 111), is one of the most effective ways of dealing with this problem. The copper barrier prevents the insects from passing from ground to the wood food they seek, because they cannot bend their bodies to crawl around the edge of the shield, and of course, it is effective in termite-infested buildings because it cuts the creatures off from the ground moisture without which they cannot live.

The subject of "Protection Against Termites" is thoroughly covered in a booklet by that title issued by this Association. Copies of this are available.

COPPER CORNICES

Sheet copper for cornices has been standard practice for years, because: (1) it is light in weight; (2) it is easily worked and shaped; (3) its fabrication and erection usually require less labor than stone, wood or terra cotta. These features, coupled with; (3) its enduring qualities and; (4) pleasing appearance, explain its universal acceptance as the most suitable material for cornices. An additional advantage is (5) safety; copper cornices do not become dislodged by the action of ice and frost.

There are so many variations in cornice design and construction that each case must be considered on its merits as an individual problem in detail. However, the following notes apply in principle to all.

—Loose-lock seams should be used between sections, their locations being determined by contour and design, and the fact that water must not be allowed to enter:

—If the sheet covering the deck is more than 24″ wide a cap and base flashing should be used at the wall:

—Sheets should not be nailed when the supporting structure is wood, brass (or other copper-alloy) screws with lead washers being used for such fastenings:

—Metal supports, braces, and lookouts required by building codes should be of brass (or other copper-alloy) and copper-alloy bolts or screws should be used for fastening the copper to them:

—Longitudinal joints should be either loose-lock seams or expansion joints made as described for **Fig. 17,** page 23:

—When sheets are more than 36″ long enlarged holes should be provided for all screws or bolts so movement will not be restricted. **Fig. 50, Plate X,** shows the copper caps used over such enlarged holes.

Below are set down the salient points in the construction of copper cornices:—

(1)—Use at least 20-oz. cold-rolled copper, either plain or crimped, for panels, profiles and moldings. Ornaments and enrichments can be soft copper;

(2)—All metal supports and fastenings must be brass (or other copper-alloy). If ferrous metal is used it must be insulated from the copper;

(3)—Sufficient lookouts, braces, supports, stiffeners, and anchors must be included to assure rigid construction;

(4)—Brass (or other copper-alloy) bolts or screws with lead washers in slotted holes are used where there must be room for movement;

(5)—Sufficient loose locks and expansion joints must be provided to take care of expansion and contraction;

(6)—Tight seams are riveted and soldered;

(7)—Ornaments, embellishments, and other enrichments are soldered to plane surfaces, and riveted if they are large and heavy;

(8)—Drip edges are always used where setbacks occur at the bottom of vertical faces.

SECTION IV—ROOF DRAINAGE

The ideal roof drainage system is designed to carry away water quickly and to avoid pockets in which snow and ice can collect. Roofs, flashings and valleys shed water directly and speedily to gutters, the outlets of which transfer their horizontal flow into vertical leader flow with maximum hydraulic efficiency. From the outlets the leaders conduct the roof runoff to ground or sewer with accelerating velocity.

Gutters are conduits, troughs, channels in which water flows: they are *not* tanks in which water is stored. Therefore, gutters and leaders need only be large enough to carry the maximum amount of water flowing into them. Making them any larger is wasteful of material, bad hydraulics, and a fruitful source of trouble.

When outlets of badly designed gutters get plugged—as too often happens—by leaves, paper, or snow and ice, the only notice given is the post-damage one of wet walls and ceilings, because water rises above and flows down behind the inside of the gutter-linings. But if the gutter is properly designed—of minimum depth, with the outside edge lower than the inside, or with a scupper—water running down the outside of the building gives immediate notice of trouble aloft, and no water damage is done to the interior of the building.

In one very large building, with unusually deep and lengthy copper gutters draining large copper roof areas, every outlet is equipped with an electric heating-element. During the winter months the current is turned on every time it starts to rain or snow. As a result the outlets are always open, and though the snow-packed gutters often freeze, with each thaw, however slight, some water readily makes its way into the leaders. Thus the gutters perform their sole function of troughs with maximum efficiency.

The importance of proper application of flashings at the critical points of a roof is well known. The construction at points where roofs or valleys meet gutters, and at leaders, outlets, scuppers and strainers has been demonstrated to be equally important. Some drainage systems that have been entirely satisfactory in design have given trouble because of faulty construction.

The most common faults in gutter and drainage design are:

1. Gutters too large and too flat;
2. Inadequate provision for expansion and contraction;
3. Improper spacing or number of leaders;
4. Outlets too small or of improper shape;
5. Lack of scuppers or overflow drains;
6. Improper provision for snow and ice.

If the gutter is too large and the outlets cannot empty it fast enough, water backs up behind flashings and leaks into the building, or spills over the outside to cause staining and other troubles. If built-in gutters are too deep and too flat, the expansive thrust of freezing ice may cause breaks and leaks.

Expansion and contraction must be cared for, or the metal will buckle and break, and leaks result.

If the leaders are insufficient in number, too small, or spaced too far apart, the water is not carried away from danger points fast enough.

If scuppers or overflow drains (see **Plate XXIX**) are not provided, outlet stoppage will cause an overflow into the building.

Gutters should have all the slope possible, which means high points and short runs between carefully spaced outlets. This statement refers essentially to narrow gutters such as the stock shapes illustrated on pages 121 and 122, and holds good in the great majority of copper gutter installations. However, it should be noted that gutters having flat bottoms exceeding 12 inches in width should not be sloped more than 2%, or 2 feet in 100. Laboratory and field observations of the behavior of water flowing down flat troughs indicate that when the width and slope exceed the above limits the movement is impeded by the formation of cross ripples, so that the c.f.s. delivery of water is substantially reduced.

Outlets should be fitted with guards to prevent leaves, twigs, sticks, paper and other rubbish from clogging the drains. But improper strainers often do more harm than good by impeding drainage entrance into the outlets, or by collapsing and being washed part way down to jam the leaders. Only copper-wire, or cast brass or bronze strainers, should be used. The steady attack of flowing water will soon break down a corrodible material.

Cast brass or bronze strainers are best for large outlets as they have greater strength than wire. They are in general use on large structures (see **Plate XXIX**). Copper-wire, or basket, strainers (see **Fig. 147**) are made for outlets up to 8″ in diameter.

Whether the building be large or small—urban or rural—good maintenance practice calls for roof and gutter inspection (and cleaning) at least twice a year. Many building superintendents check their gutters quarterly. All prudent architects, and all reputable builders of small houses for sale, will emphasize to their clients and customers the necessity for cleaning gutters, outlets and leaders every fall and every spring.

PROPORTIONING GUTTERS, LEADERS AND OUTLETS

The design of a drainage system as far as capacity is concerned depends on the amount of water to be handled. This in turn depends upon the intensity and duration of rainfall in the particular locality.

The roof area used in computations should be the actual area and not the horizontal projection, or plan, of the area. Rain seldom falls vertically, and the maximum condition exists when it strikes perpendicular to the roof plane, making the total area effective.

RAINFALL DATA

As conditions throughout the country vary rainfall data should apply to the locality in which the structure is to be built.

Fig. 128, below, is a table compiled from charts of the U. S. Department of Labor that show the occurrence and duration of rainfall intensities in 23 cities, for which the U. S. Weather Bureau has included data of excessive rainfalls in its annual reports. In most cases these records begin about 1896, but as few storms were recorded and measured in the early years there may be some discrepancies, particularly for the cities west of the Mississippi River. Where absolute safety is necessary this fact should be borne in mind. These records were used unadjusted in compiling the table.

The type of structure for which the drainage system is being designed must also be considered. A storm of maximum intensity may occur only once in twenty years

	A Storms which should be exceeded only once in 5 years		B Storms which should be exceeded only once in 10 years		C Maximum record Storms	
	Intensity in Ins./Hr. lasting 5 minutes	Sq. Ft. of actual roof drained per Sq. In. of Leader area	Intensity in Ins./Hr. lasting 5 minutes	Sq. Ft. of actual roof drained per Sq. In. of Leader area	Intensity in Ins./Hr. lasting 5 minutes	Sq. Ft. of actual roof drained per Sq. In. of Leader area
Albany, N. Y.	6	200	7	175	7	175
Atlanta, Ga.	7	175	7	175	9	130
Boston, Mass.	5	240	6	200	7	175
Buffalo, N. Y.	5	240	5	240	10	120
Chicago, Ill.	6	200	7	175	7	175
Detroit, Mich.	6	200	6	200	7	175
Duluth, Minn.	5	240	6	200	7	175
Kansas City, Mo.	7	175	8	150	10	120
Knoxville, Tenn.	5	240	6	200	6	200
Louisville, Ky.	6	200	7	175	8	150
Memphis, Tenn.	5	240	6	200	10	120
Montgomery, Ala.	7	175	7	175	7	175
New Orleans, La.	7	175	7	175	8	150
New York City, N. Y.	6	200	8	150	9	130
Norfolk, Va.	6	200	7	175	8	150
Philadelphia, Pa.	6	200	7	175	8	150
Pittsburgh, Pa.	6	200	6	200	7	175
St. Louis, Mo.	6	200	8	150	11	110
St. Paul, Minn.	6	200	6	200	8	150
San Francisco, Cal.	2	600	2	600	3	400
Savannah, Ga.	6	200	7	175	8	150
Seattle, Wash.	2	600	2	600	2	600
Washington, D. C.	6	200	7	175	8	150

FIG. 128—RAINFALL DATA AND DRAINAGE FACTORS

in a certain locality, while a lower rainfall intensity will be exceeded only once in ten years. If gutter overflow is a matter of inconvenience only, or if the design can incorporate auxiliary drains to care for the excess, the lower intensity may well be used. In residential construction, for instance, no great harm need result if water spills out of gutters during one storm in five years, and the use of the corresponding intensity of rainfall rather than one that will never be exceeded can effect considerable saving.

On the other hand, the architect who is designing a monumental building—where the construction of built-in gutters with cornices, parapets, etc., is such that an overflow would have most serious consequences—can design only for maximum conditions.

LEADER DESIGN

In the design of leaders, practical considerations apply as well as principles of hydraulics. In a given time more water will drop through a vertical pipe than will flow in a horizontal trough of equal area. Therefore it appears that the leader could well be much smaller than the gutter and still take care of all the water coming to it; moreover, it might seem that the leader could be tapered as the velocity of the falling water increases with the fall.

These inferences would follow if only pure hydraulics were involved, but experience has shown that, due to practical considerations, such as frequent plugging by debris, or collapse because of the vacuum created in long drops when a plugged outlet is suddenly cleaned, the following rules must be followed:

(1)—4″ round, square, or rectangular leaders are the minimum (except for small porches);

(2)—The leader area is constant throughout its length;

(3)—Long leader drops are constructed with leader heads every 40 ft., to admit air and prevent vacuums;

(4)—Maximum spacing of leaders must not exceed 75 feet.

With item (4) in mind, the locations of the leaders are first determined. If possible, they should be placed near the corners of the building so that the gutter water will not have to flow far beyond a sharp turn. Building expansion joints, because they necessarily are located at high points in the gutter, will often govern leader location. Of course, appearance and other architectural considerations will also play a part.

With the locations determined, the areas tributary to each leader should be computed. Actual roof areas should be used, not plan areas. These areas are then divided by the proper factor taken from the table in **Fig. 128** and the required areas in square inches of the leaders are thus determined. Then from the table in **Fig. 129** the right-sized leaders are selected.

Fig. 128 gives the intensity of rainfall that can be expected in 23 cities according to U. S. Weather Bureau records, and the corresponding amounts of roof area that one square inch of leader area will drain during such storms. The latter are based on the assumption that for an intensity of 8″ per hour, one sq. in. of leader will care for 150 sq. ft. of roof. The table is set up on three different bases. Column "A" is for conditions that may be exceeded on the average of once in five years; Column "B" for rainfalls that may be exceeded once in ten years; and Column "C" gives the maximum rainfalls yet recorded. Which column should be used in any given instance is a question of judgment for the designer.

Type	Area in Sq. In.	Nominal Leader Sizes
Plain Round	7.07 12.57 19.63 28.27	3″ 4″ 5″ 6″
Corrugated Round	5.94 11.04 17.72 25.97	3″ 4″ 5″ 6″
Polygon Octagonal	6.36 11.30 17.65 25.40	3″ 4″ 5″ 6″
Square Corrugated	3.80 7.73 11.70 18.75	1¾″ x 2¼″ (2″) 2⅜″ x 3¼″ (3″) 2¾″ x 4¼″ (4″) 3¾″ x 5″ (5″)
Plain Rectangular	3.94 6.00 8.00 12.00 20.00 24.00	1¾″ x 2¼″ 2″ x 3″ 2″ x 4″ 3″ x 4″ 4″ x 5″ 4″ x 6″
S.P.S. Pipe	7.38 12.72 20.00 28.88	3″ 4″ 5″ 6″
Cast Iron Pipe	7.07 12.57 19.64 28.27	3″ 4″ 5″ 6″

Fig. 129. Dimensions of Standard Leaders

Example:

Suppose the problem is to design the leaders for a building in Boston which is to be 120 ft. by 80 ft. with a plain gable roof having a ridge down the center and a slope of

9″ to the foot. Assume further that there will be a leader at each corner and that it seems proper to allow for one overflow in ten years.

Solution:

If the slope is 9″ per ft., the roof area on each side of the ridge is 120′ by 50′, or 6000 sq. ft., and each leader would serve 3000 sq. ft.

From Column "B" of **Fig. 128,** opposite Boston, it is found that 200 sq. ft. is the amount of roof area which 1 sq. in. of leader will serve, and accordingly a leader having an area of 15 sq. ins. is required.

By turning to **Fig. 129,** which lists the areas and dimensions of standard leaders, it is found that 5″ round or octagonal leaders are required, or that either 3¾″ x 5″ square corrugated or 4″ x 5″ plain rectangular leaders could be used.

GUTTER DESIGN

SMALL RESIDENCE WORK

As in the case with leader design, judgment plays a large part in the design of gutters. The type of structure has an important bearing. Where occasional overflow of the gutters is not a serious matter, experience has proven certain arbitrary rules entirely adequate. These are based partly on the size of the leaders, determined as outlined above.

The best type of gutter has its minimum depth equal to half and its maximum depth not exceeding three-quarters of its width. Thus width becomes the deciding factor in proportioning size. There is no reason for a gutter deeper than three-quarters of its width except for ornamental purposes, and for practical reasons it is distinctly desirable to keep the gutter shallow. Assuming that the ratio of depth to width is kept within these limits, the gutter can be referred to by width only.

The size of gutters depends upon:

(1) The number, size, and spacing of the outlets.

The gutter acts as a receiving channel to carry the water to the outlet. The slope of the gutter determines the flow toward the outlets.

(2) The slope of the roof.

A steep roof carries the water to the gutter faster than a flat one does.

(3) The style of gutter used.

Some gutters are not effective for their full depth and width. In proportioning gutters consideration of the available area is essential.

(4) A gutter less than 4″ wide is to be avoided.

In ordinary practice 4″ gutters are seldom used for they are difficult to solder and increase the labor cost. The gutter may be the same size as the leader it serves, but, of course, can not be smaller.

(5) Half-round gutters are economical and properly proportioned.

This type uses a minimum of material and insures a proper ratio of width to depth.

(6) A minimum slope of 1/16 of an inch per foot is required.

Less than this will not provide for proper flow of water in the gutter.

Based on the above, safe rules for determining the size of gutters for ordinary work are:

(1) If spacing of leaders is 20′ or less, use a gutter the same size as the leader, but not less than 4″.

(2) If spacing of leaders is more than 20′, add 1″ to the leader diameter for every 30′ (or fraction) additional spacing on peaked roofs, and add 1″ for every additional 40′ of gutter length for flat roofs.

Examples:

1. A 40′ gutter serves a 4″ leader on a flat roof. The gutter should be 5″.
2. A 75′ gutter serves a 4″ leader on a peaked roof. The gutter width is 6″.
3. A 75′ gutter serves a 4″ leader on a flat roof. The gutter width is 6″.

LARGE AND MONUMENTAL BUILDINGS

Gutter and leader installations in large buildings require liberal design to insure against any possibility of gutter overflow. Design and use requirements of monumental structures are often such that a single overflow will have most serious consequences.

For such designs the following formulae (or the charts based on them) are recommended. These are derived empirically from tests carried out on level gutters at the U. S. Bureau of Standards in Washington. By using them liberal sizes are obtained that are ample for important work. These formulae are:

For **Semicircular Gutters:** $W = 1.3\, Q^{2/5}$

For **Rectangular Gutters:** $W = 0.481\, m^{-4/7}\, l^{3/28}\, Q^{5/14}$

where, W = width of gutter in feet

m = depth/width

l = length of gutter in feet

Q = total gutter inflow (cu. ft. sec.)

SEMI CIRCULAR GUTTERS

WIDTH OF GUTTER FOR GIVEN ROOF AREAS AND RAINFALL INTENSITIES

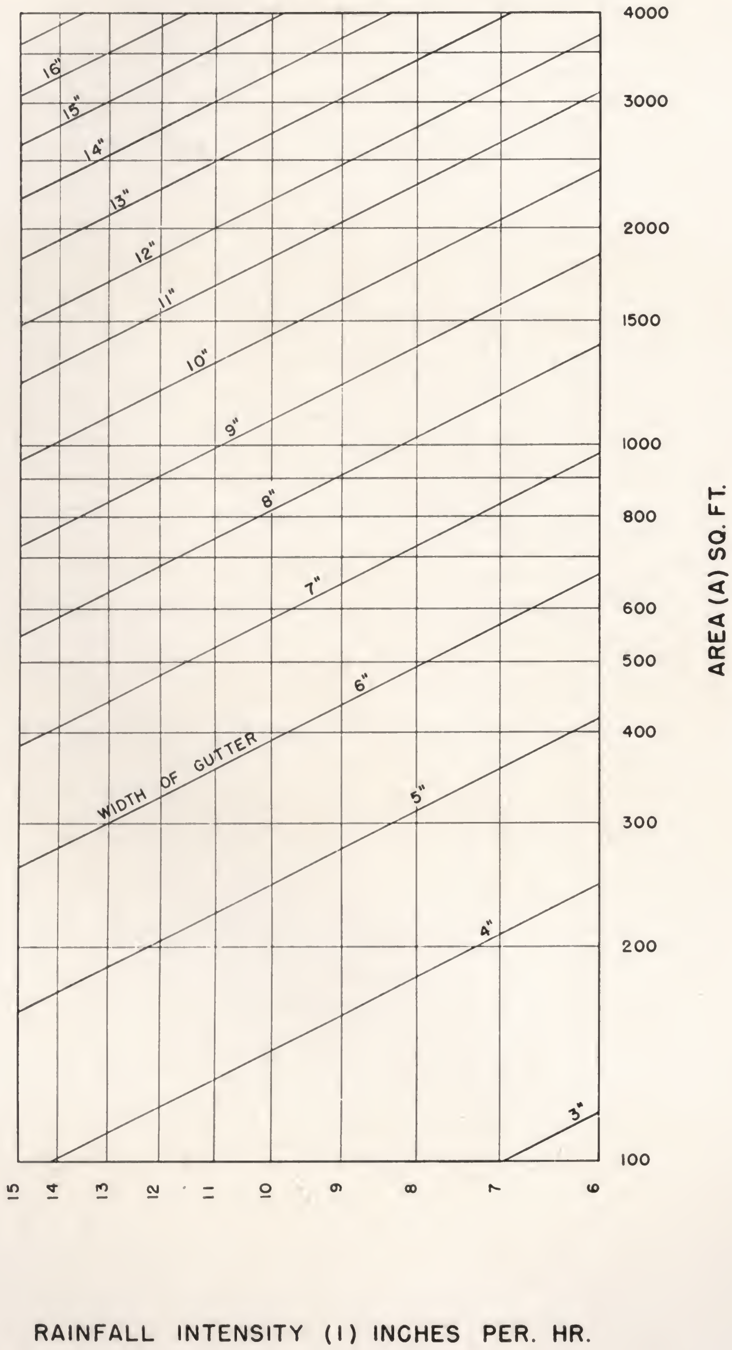
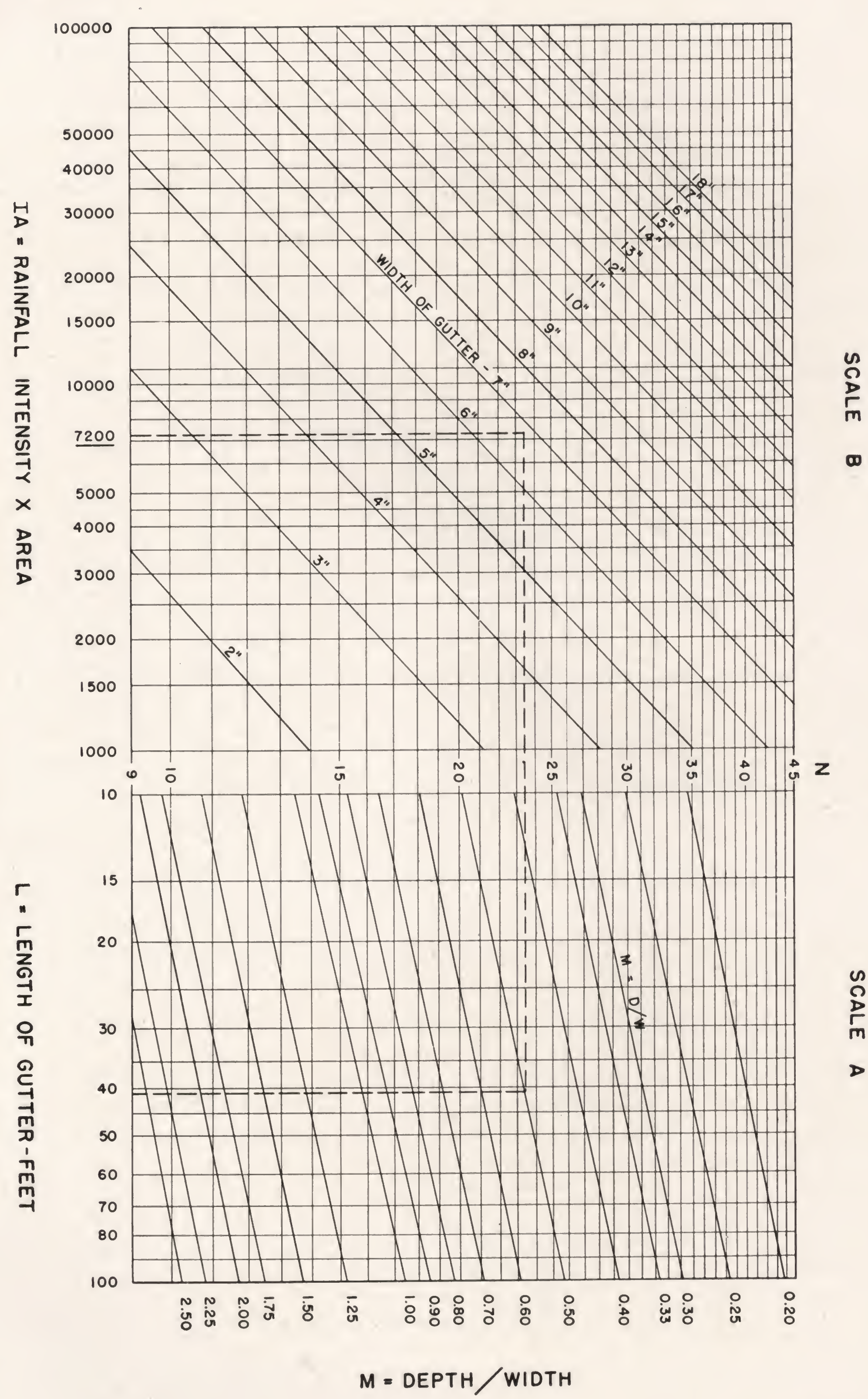


FIG. 130



RECTANGULAR GUTTERS
WIDTH OF GUTTER FOR GIVEN ROOF
AREAS AND RAINFALL INTENSITIES

FIG. 131

The charts on **Figs. 130** and **131** have been plotted from these formulae so that Gutter Widths may be read directly in Inches in terms of Rainfall Intensities and tributary Roof Areas. They are for level gutters. Where the slope exceeds 2% the gutter should be narrowed and deepened to reduce the cavitating action of wave crests that reduces velocities on wide, smooth slopes steeper than 1 on 50.

Example 1: (Semicircular)

A semicircular gutter is required to drain a roof 20′ x 40′, located in Buffalo.

Solution:

In **Fig. 128,** third column, the Maximum Rainfall Intensity, I, of 10″ per hour is given for Buffalo. The roof Area, A, is 800 sq. ft. On the graph of **Fig. 130** find 800 on the bottom scale, pass vertically to the horizontal line representing an I of 10″ per hour. The intersection falls nearly on the line marked 8″ which, accordingly, is the width of the gutter required. If the intersection falls between two sizes, the larger one should, of course, be used.

Example 2: (Rectangular)

A roof area 40′ long by 20′ wide is to be drained by a rectangular level gutter, the depth of the gutter being half of the width. The building is located in Atlanta.

Solution:

From the third column of **Fig. 128** the Maximum Rainfall Intensity, I, for Atlanta is taken at 9″ per hour. From the proportions of the gutter, $m = 0.5$. The length of gutter, is l, is 40′, and the area drained by it, A, is 800 sq. ft. Thence IA = 7,200.

On the chart "Rectangular Gutters," **Fig. 131,** find the vertical line representing $l = 40$. Proceed vertically along this to its intersection with the oblique line representing $m = 0.5$. Thence pass to the left through N = 23.3 (an equalizing Constant) to intersect the vertical line representing IA = 7,200. The point of intersection occurs between the oblique lines representing gutter widths of 6″ and 7″. The required width of gutter is, therefore, 7″ and its depth need be only 3½″.

The required sizes of level gutters of other than semicircular or rectangular shapes can be determined closely by finding the semicircle or rectangle of the same area that most closely fits the irregular cross-section. This is done by drawing the required shape to any convenient scale and making the fit graphically so that the areas of excess and shortage will be equal. A trapezoidal shape of depth equal to one-half the width is closely fitted by a semicircle. A molded gutter can usually be approximated by a rectangle. This method was checked experimentally in laboratory tests, and the discrepancies found to be very small.

OUTLET DESIGN

The design of outlets is of great importance. If they are not properly proportioned the horizontal gutter flow will not go down the leader fast enough to prevent overflow during flash storms.

As an integral part of this subject the reader is referred to the discussion of **Outlets for Gutters** on page 96, where the hydraulic phenomena involved in the change of flow of liquids from horizontal to vertical are explained.

Experience and tests show that outlets should be elliptical or rectangular in plan with the larger dimension in the direction of the gutter flow.

For large semicircular gutters, outlets should be as long as the gutter width and two-thirds as wide.

For rectangular gutters 6″ wide or less, the outlet should be about 2″ less in width than the gutter and as long as the gutter is wide.

For larger gutters it is safer to make the outlet the full gutter width and about one and a half times as long.

The area of the top of the outlet, determined as just outlined, is tapered down to the size of the leader, so that it is shaped like the frustrum of a cone or pyramid, according to the formula:

$$h = \frac{A^2}{630\, d^4}$$

where h = inches of head on the leader inlet, (i.e. depth of outlet);
A = sq. ft. of tributary roof area;
d = inches of leader diameter (plain round or equivalent of other shapes.)

EXAMPLE:

From **Example 2** above, the tributary roof area is 800 sq. ft., and the gutter width is 7 inches. So, from **Fig. 128** the leader area is determined as 6.2 sq. ins.; and from **Fig. 129** we find that a 4″ corrugated round leader with an area of 11.04 sq. ins. is closest to this area.

Then, from the foregoing formulae, it follows that the top of the outlet (bottom of gutter) should be 7″ wide and 10½″ long, and that its depth should be:

$$h = \frac{640{,}000}{630 \times 198} = 5 + \text{ins.}$$

SECTION V

FACTORY-MADE ROOFING PRODUCTS

In **Fig. 132** are shown the various parts of gutters, leaders and accessories made and stocked by manufacturers and distributors throughout the country. As rainfall and local prejudices show great variations it is not to be expected that all warehouses will carry the same stock. However, any of the pieces here illustrated, and many others, can be furnished on short notice anywhere.

While there is some difference in nomenclature across the country, manufacturers and the trade in general use the designations given.

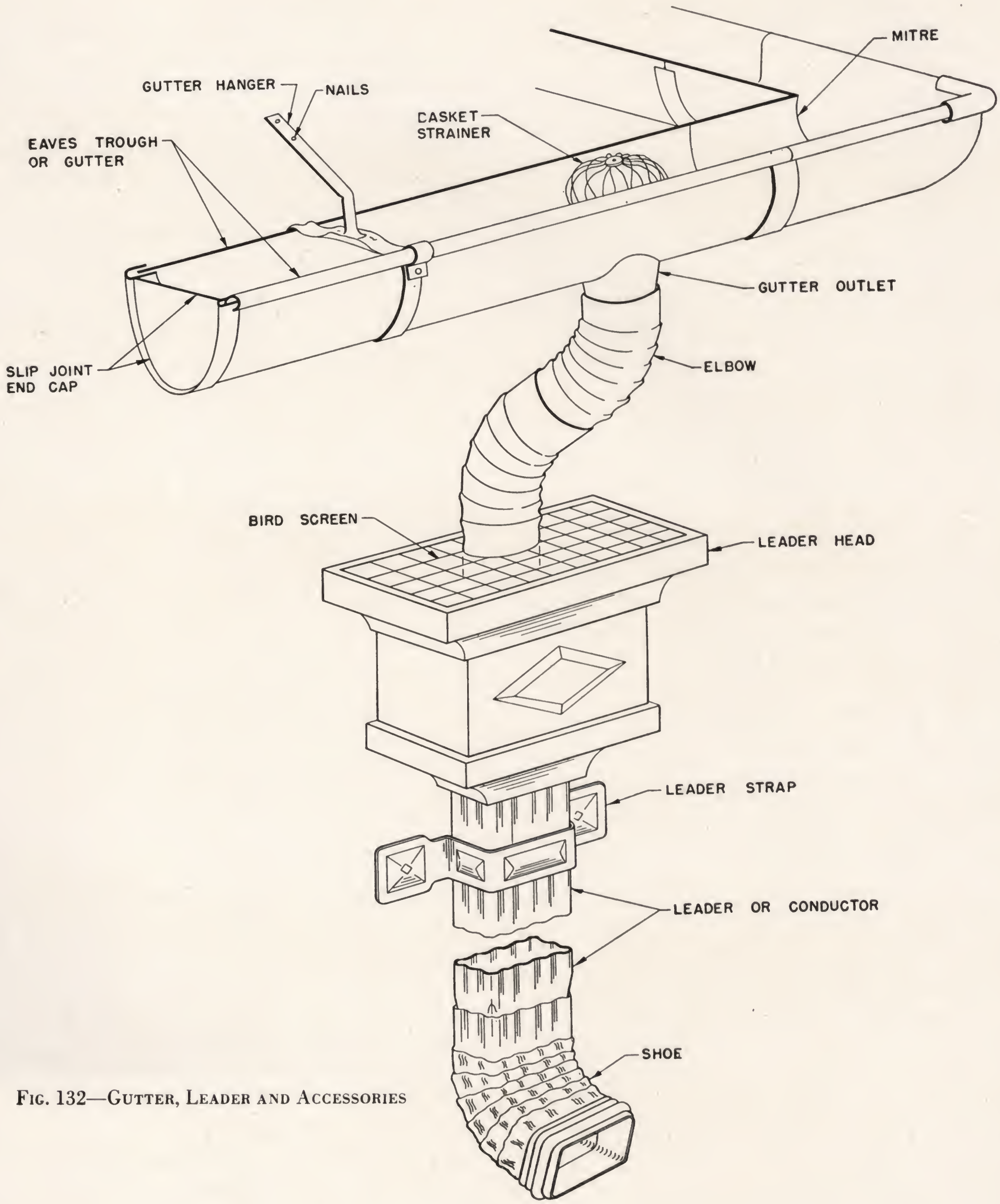
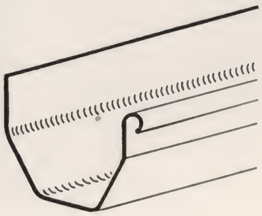


FIG. 132—GUTTER, LEADER AND ACCESSORIES

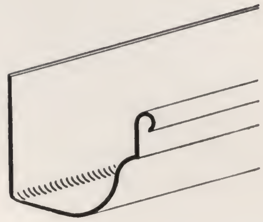


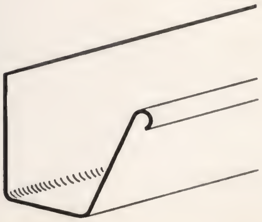
STYLE C

5″ wide, 3½″ deep, 12″ girth.
6″ " , 4¼″ " , 14″ " .
7″ " , 4½″ " , 16″ " .

STYLE G

6″ wide, 5⅝″ deep, 18″ girth.
7″ " , 6″ " , 20″ " .
8″ " , 6⅝″ " , 22″ " .



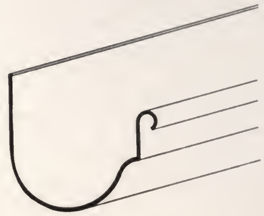


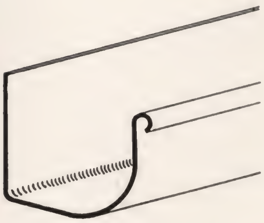
STYLE D

6″ wide, 4″ deep, 18″ girth.
7″ " , 5″ " , 20″ " .
8″ " , 5¾″ " , 22″ " .

STYLE H

6″ wide, 4″ deep, 14″ girth.
7″ " , 4¾″ " , 16″ " .
8″ " , 5½″ " , 18″ " .



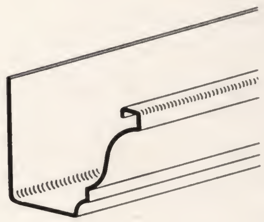


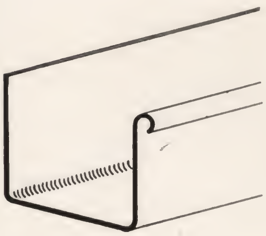
STYLE E

6″ wide, 3⅜″ deep, 15″ girth.
7″ " , 4¾″ " , 18″ " .
8″ " , 6½″ " , 22″ " .

STYLE J

6″ wide, 5½″ deep, 18″ girth.
7″ " , 6¼″ " , 20″ " .
8″ " , 6⅞″ " , 22″ " .





STYLE F

6″ wide, 5½″ deep, 18″ girth.
7″ " , 5¾″ " , 20″ " .
8″ " , 6″ " , 22″ " .

STYLE K

4¾″ wide, 3¾″ deep, 12″ girth.
6″ " , 4¾″ " , 15″ " .
8″ " , 6″ " , 20″ " .

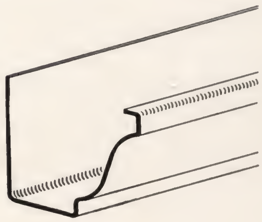


Fig. 133—Molded, or Box, Gutters

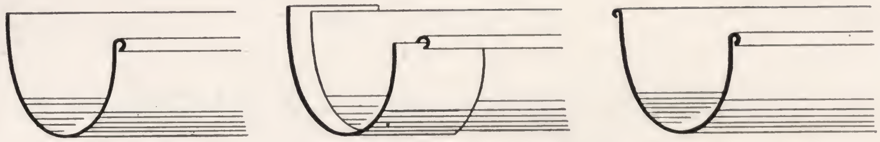
MOLDED COPPER GUTTERS

Molded gutters of quite different style are shown in **Fig. 133.** As the call for these does not warrant stocking all the shapes shown, local distributors usually have only a few of the locally popular ones, and have the others made up to order. These styles do not sell as well as Single-Bead Eaves Trough, because they require more metal for the same effective area, and therefore cost more. They are made of 16-oz. copper in 10-ft. lengths, and vary from 3″ wide by 2″ deep (Style **K**), girth 8″, to 8″ wide by 6⅞″ deep (Style **J**), girth 22″.

A 5″ half-round Single-Bead Eaves Trough has a girth of 10″. Style **C** gutter, 5″ wide, has a girth of 12″, 20% more. A 6″ half-round Single-Bead Eaves Trough has a girth of 12¼″. Style **C** and **H** gutters have a 14″ girth; style **D,** 15″; Styles **G** and **J,** 18″. The increase in copper varies from 14 to 46%.

However, molded gutters are presently in great demand by house-builders, for their use makes it possible to eliminate the conventional wood cornice that goes with the popular "American Colonial" style of architecture, thereby saving both material and labor.

Style **K** in 10″ and 12″ girths is the most popular. It is used for 90% of all molded gutters in the United States.



Single-Bead Lap Joint Single-Bead Slip Joint Double-Bead Lap Joint

FIG. 134—HALF-ROUND GUTTERS

HALF-ROUND EAVES TROUGH

Molded gutters, including half-round, are made in several designs. The most commonly used is the 16-oz. Single-Bead, half-round Eaves Trough illustrated in **Fig. 134**.

Two types of gutter, Lap Joint and Slip Joint, are stocked throughout the country and are carried in sizes up to 6″ by practically every sheet-metal contractor. Sizes above 6″ are not in common use, as buildings requiring gutters of a larger size usually have them built in or made a part of the cornice. Sizes up to 10″ may be had, and are stocked in the warehouses of most of the large distributors in the principal cities.

Fig. 134 also shows the Double-Bead Eaves Trough, which is made in the same two types as the Single-Bead. As may be noted from its contour, it is somewhat stiffer than the latter. On account of this stiffness it is possible to place the hangers farther apart than when the Single-Bead is used. However, it is more difficult to line the inside bead against the roof edge, and to secure the hanger. It also costs more than the Single-Bead.

Half-round Eaves Trough is made in 10-ft. lengths with both lap- and slip-joint ends. Slip joints (**Fig. 135**) provide for expansion and contraction in long runs of gutters. They are set about every three lengths, or 30′, apart, the joints between being lapped and soldered. The slip joint is not soldered. In some localities the practice is to lap the lengths about 3″ and use no solder or slip joints. This practice is satisfactory where there is considerable slope to the gutter and where there is no danger of leaves, etc., stopping the flow toward the outlet. It is obvious that all joints in gutters should be made with the flow.

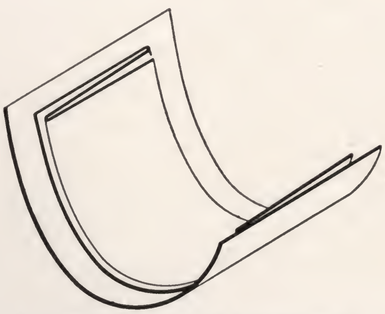
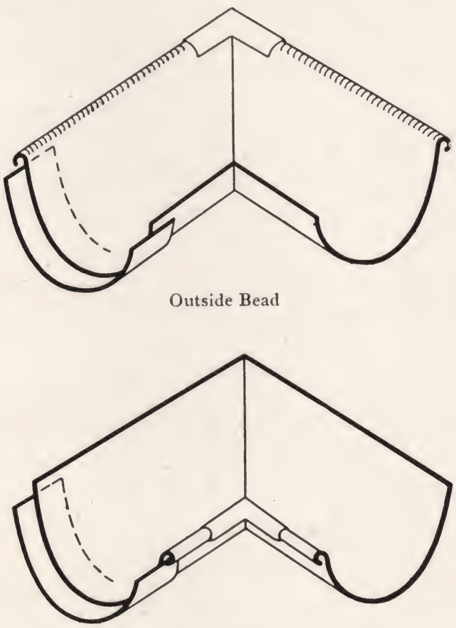


FIG. 135—SLIP JOINT CONNECTION

MITRES

In **Fig. 136** are shown Single-Bead, half-round, outside and inside mitres. They are regularly stocked in 16-oz. copper, with and without the slip joint connection illustrated, and are also available with the double-bead. In ordering, the bead should be stated as well as whether “inside” or “outside” mitres are wanted; and if slip joints, whether “rights” or “lefts.”



Outside Bead

Inside Bead

FIG. 136—GUTTER MITRES—SINGLE-BEAD TYPE

STOCK SHAPES ARE ECONOMICAL

Section V is intended to be a handy reference for stock types and styles of roofing accessories that are widely available and find general use in residential construction. This information is important to sheet-metal contractors when submitting estimates and making promise dates for a job, and to architects when writing copper roofing accessories into specifications. For by using stock shapes costs are kept at the minimum and, moreover, there will be no long waits for delivery of special pieces.

END PIECES, CAPS AND OUTLETS

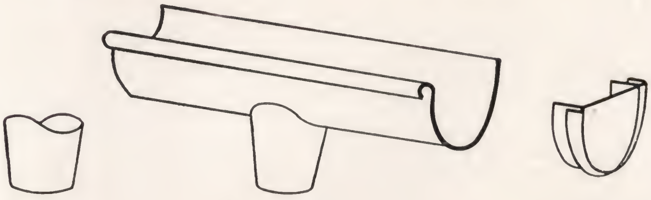


Fig. 137—Outlet, Assembly and End Cap

Fig. 137 shows the usual accessories for half-round Eaves Trough that are carried in stock or can be quickly supplied. As these pieces are factory-made they are generally of strong construction. Their use is recommended.

SIZES (INCHES) OF OUTLETS AND END PIECES

	OUTLETS			END PIECES		
Nom. Size	Diameter		Length	Width	Depth	Length
	Top	Bottom				
2	2½	1⅞	3⅛	4½	2¼	12
3	3¼	2¼	2⅞	4½ 5½ 6½	2¼ 2¾ 3¼	12 12 12
4	4⅛	3⅝	2¼	5½ 6½	2¾ 3¼	12 12

Outlets can be had, round and square, in from 2″ to 6″ sizes, and are flanged at the top (not shown in **Fig. 137-A**) for soldering to the gutter.

End Pieces for Style **K** Molded Gutter (**Fig. 133,** page 121) are available in 10″ and 12″ girths.

The slip joint End Cap shown in **Fig. 137-C** is made for 3½″, 4″, 5″, 6″ and 7″ gutters. Lap joint End Caps, that fit outside instead of inside the gutter, are made in 4″, 5″ and 6″ sizes.

GUTTER HANGERS

There are many kinds of copper hangers on the market, most of which are satisfactory for the special conditions for which they are made. Several varieties, but by no means a complete selection of those available, are illustrated in **Figs. 138** and **140.**

(No. 12 has Bronze Circle for Double-Bead Gutters; Other Circles are for Single-Bead Gutters.)

Fig. 138—Bronze and Copper Hangers—Shank-and-Circle Type

Fig. 138 illustrates some of the bronze and copper shank-and-circle type of hangers. These may be made of either cast or wrought metal. They can be adjusted to give the gutter the necessary slope by attaching the circle part to the shank at different heights. The shank is attached when the building is erected and the gutters hung later, after the painting is done, thus avoiding the chance of damage to the gutters by the painters' scaffolding and ladders. The gutter is held in the hanger by the Bronze Spring Clip shown in **Fig. 139.**

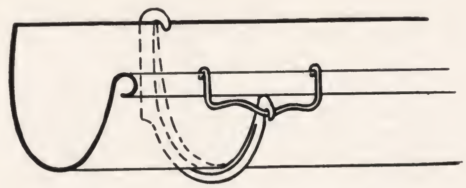


Fig. 139—Bronze Wire Spring Clip

Four types of wrought hangers are shown in **Fig. 140.** With a Single-Bead gutter it is usual to use a type of hanger that encircles the gutter, whereas with a Double-Bead, not shown below, it is possible to have a hanger that is attached only to the two beads and has no part going under the gutter proper. These wrought hangers are moderately priced, and are used extensively. Strap hangers are simple to apply and lend themselves to almost every type of eave.

The spacing of cast or strap hangers should not exceed 36″, and even closer spacing may be used to advantage.

In specifying the shank-and-circle type of hangers, be sure to give the circle size (corresponding to the gutter size, e.g. 4″, 5″, etc.) as well as the number of the type of shank selected (e.g. No. 2, No. 7, etc. See **Fig. 138**).

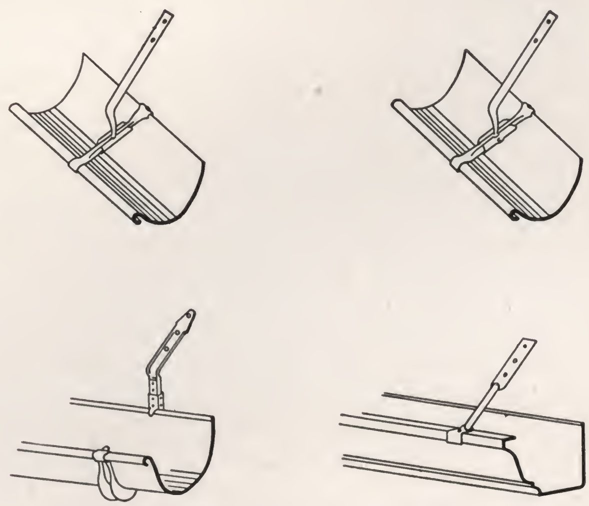


Fig. 140—Wrought Copper Strap Hangers

LEADERS, DOWNSPOUTS, CONDUCTORS

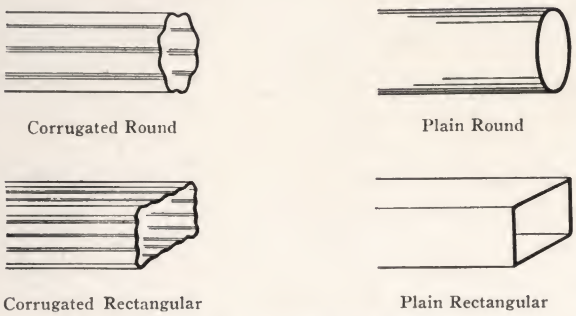


FIG. 141—STANDARD LEADERS

As may be seen in **Fig. 141** leaders, or downspouts, are made in four standard shapes. Special designs, such as octagonal and V-crimped, may also be had. The plain shapes are not widely used because they do not seem to resist freezing as well as do the corrugated ones. Moreover the latter are more pleasing in appearance when in place than are the plain ones. Leaders are regularly furnished of 16-oz. copper in 10′ lengths and in the sizes listed in **Fig. 129** (page 115).

LEADER HEADS AND STRAPS

Three typical ornamental leader straps regularly carried in stock are illustrated in **Fig. 142.** The two upper ones, shown flat, as they are supplied, support any shape of leader. The lower one is a 3-piece notched and fitted device used on 2″ x 3″ and 3″ x 4″ rectangular leaders only.

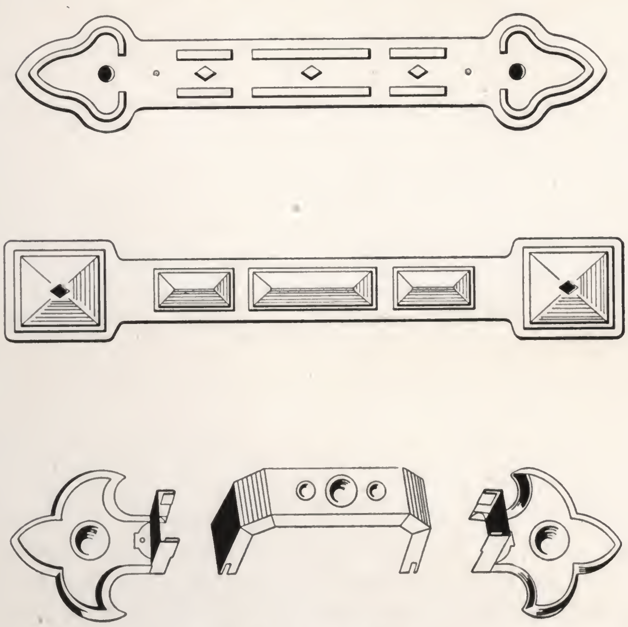


FIG. 142—LEADER STRAPS

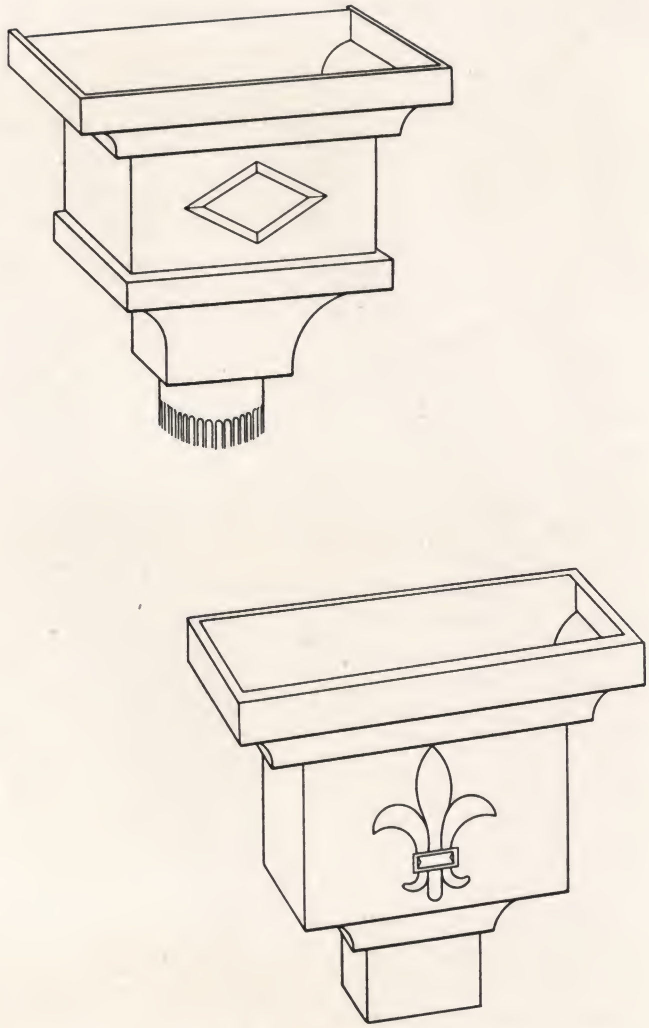
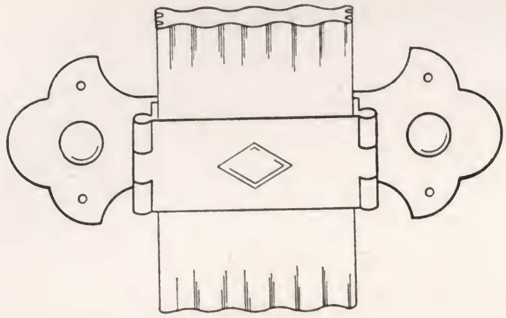


FIG. 143—LEADER HEADS

Fig. 143 shows two of several stock ornamental leader heads that are suited to almost any style of architecture. All leader heads are available with round or square (rectangular) outlets. Any of these stock patterns can be supplied lead-coated.

Architects often design special leader heads and straps to harmonize with the individual architectural style of a building. These special designs, with or without such enrichments as bosses, studs, repoussé relief, raised or depressed panels, etc., are made to order, in plain or lead-coated copper, from the architect's drawings by the manufacturers of stock roofing accessories. In making such designs the architect should have in mind: (a) the distance from the ground, lest the embellishment be in too small scale to be seen; (b) the thickness of the sheet, 16-oz. being too thin for deep incising and intricate patterns.



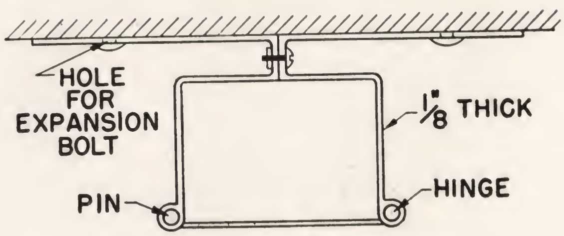


FIG. 144—HINGED LEADER STRAP

Fig. 144 shows a heavy, hinged bronze strap used on square corrugated leaders. It is made of solid cast bronze and is fastened to the wall by 4 expansion bolts, the holes for which are spaced to fit such joints. When installed it stands 1″ away from the wall. The right side of the strap is hinged. The left side has a loose pin that permits the leader to be removed without taking the strap off the wall. The machine screw can be adjusted to fit variations in leader sizes. These leader straps can be had in the following sizes: 3″ and 4″ round, 3″, 4″ and 5″ square.

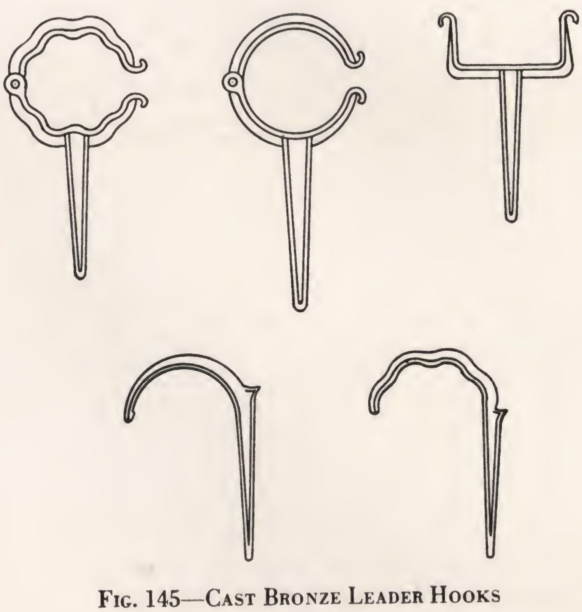


FIG. 145—CAST BRONZE LEADER HOOKS

Fig. 145 illustrates common types of leader hooks. Shanks are available in different lengths, designed either for wood or brick drive. The three hooks in the upper row are driven into wall before the leader is placed; the two lower ones are set with the leader. Leader hooks should not be more than 6 feet apart.

Bronze Hinged hooks, round plain and corrugated (see top row, **Fig. 145**), are made with brick drive for 2″ to 6″ leaders, and with wood drive for 2″, 3″ and 4″ leaders. Bronze Clasp hooks, similar to the hinged type except for separate drives that permit close adjustment of the distance between leader and wall, are made round plain or corrugated, and square, for 3″ to 6″ leaders. The righthand cut (top row) shows a Wired hook. This type can be had for 2″ to 6″ square, and for 3″ and 4″ round leaders.

The bottom row of **Fig. 145** illustrates bronze Sickle hooks that are made for round leaders only.

Leaders are held in Hinged, Clasp and Wired hooks by copper wire twisted around the points.

COPPER ELBOWS AND SHOES

Copper elbows and shoes are stock leader accessories, and are illustrated in **Fig. 146**. They are made in many styles and shapes to fit every condition encountered in building. For example, square elbows and shoes are made in two styles: **A**, which has its long side; and **B**, which has its short side; against the wall. The use of such pieces is recommended.

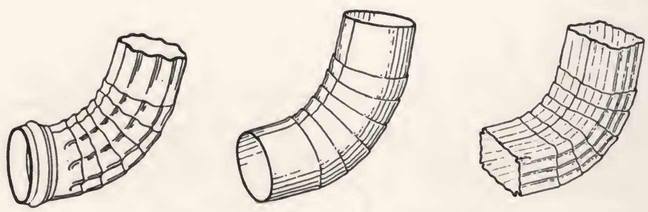


FIG. 146—SHOES AND ELBOWS

The lefthand cut shows the shoe that is always used to finish leaders that discharge at ground level. The open ends of all shoes, as can be seen, are strongly reinforced to resist denting. Shoes, with 75° angle only, are available in the following shapes and sizes: Round, plain or corrugated—2″ to 6″; Square, plain or corrugated—2″ to 5″.

Copper elbows, shown in the center and righthand cuts, are available, round or square, plain and corrugated, for 2″ to 6″ leaders. They are made in four types: No. 1—45°; No. 2—60°; No. 3—75°; No. 4—90°.

OUTLET STRAINERS

Wire-basket and cast metal strainers of stock design generally carried by jobbers and sheet-metal contractors are shown in **Fig. 147.** Strainers of heavier design can be made up quickly to specification. The wire type can be had up to 8″ round and 4″ x 6″ rectangular; the cast bronze type up to 8″ round and 3″ x 4″ rectangular.

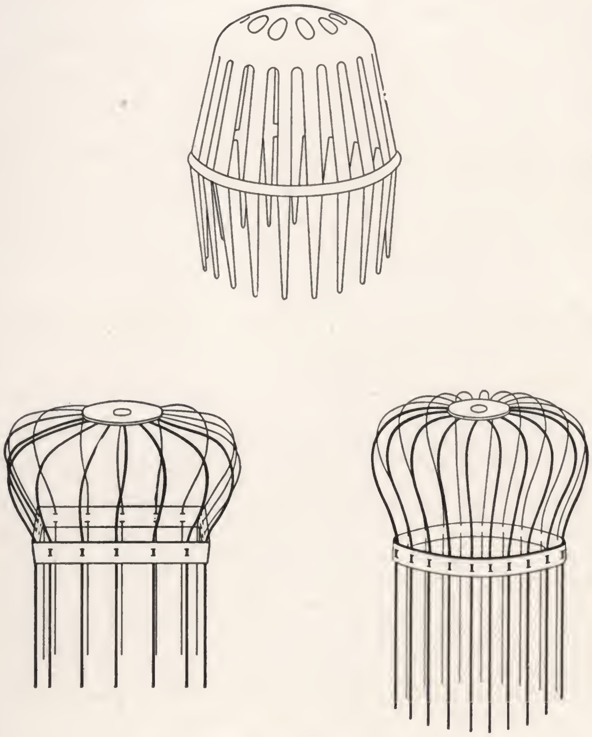


Fig. 147—Outlet Strainers

Every outlet should be provided with strainers. Especially is this essential when the leaders are small or have any elbows, etc., where leaves are likely to stick and clog the leader. For large installations on flat roofs heavy, cast brass strainers are used. (See **Plate XIX**).

SNOW GUARDS

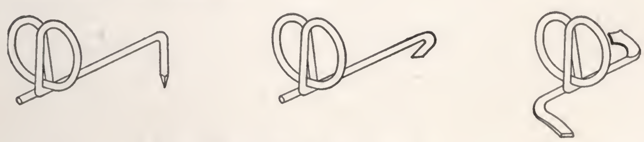


Fig. 148—Wire Snow Guards

Snow guards are an inconspicuous and inexpensive protection against both personal and property damage. Doorways must be safeguarded against injury to people from sliding snow and ice; and on many buildings there are places where the surrounding roofing must be protected from damage. Snow sliding off high roofs often tears away gutters and smashes cornices, canopies and other projections below the eaves.

Snowguards are of two general types. The simpler form consists of No. 9 B.W.G. copper (copper-alloy) wire formed as in **Fig. 148** to stand about 2″ high on the roof. The lefthand type is for new roofs. Its point is driven into the sheathing so that the butt of the slate (or tile) rests against the loop. The center type is made to slip up and hook over the upper edges of slate roofs already laid. The righthand type is also designed for old roofs. It has friction points that grip the slates (or tiles). On copper roofs an adaptation of this is used, the flat ends being soldered to the sheets.

On large buildings a more substantial type, as in **Fig. 149,** is used. The cast bronze brackets can be adjusted to

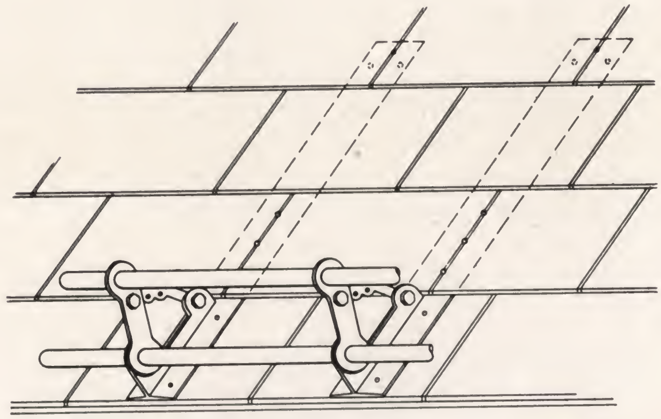


Fig. 149—Adjustable Bracket and Pipe Snow Guard

fit any slope. The fastening plate, also of bronze, is secured to the roof sheathing by bronze bolts. Brass pipes, ½″ or ¾″, run between the brackets in banks of 2 (as shown) or 3. Such brackets are spaced not more than 6′ apart, lest the weight of heavy, wet snow bend the pipes and rip the bolts out of the roof.

SECTION VI—SPECIFICATIONS

It seems hardly necessary to stress the importance of good specifications—with everything spelled out—to assure proper application and long service of building materials and equipment. However, too often specifications are meagre and vague where they should be sufficiently detailed to cover every point and stage of material, installation and workmanship, thus allowing one, and only one, interpretation. Moreover, a specification must be complete enough to implement, amplify, explain and coordinate the drawings.

A good specification safeguards all the parties to a contract. It produces uniform bids by reliable contractors and wards off the unscrupulous bidder whose low bid is based on ambiguities or omissions that suggest ways of skimping on workmanship and materials, or of accumulating a long list of extras.

Sheet-copper specifications, for large jobs particularly, should ask bidders to include in their bids the total square feet of roofing and the total weight of copper required. Such figures will show up any irregularities before the contract is signed. For the weight of metal divided by the area to be covered will give a close check on the weight of sheets to be used, and the number of square feet is a good basis for comparing the different bidders' interpretations of the plans and specifications.

STANDARD SPECIFICATIONS FOR SHEET-COPPER WORK

(Covering in detail Roofing, Flashings, Roof-Drainage, etc.)

NOTES

(a) Wherever in this specification Alternate Methods of doing work are described, they are designated by letter in order of recommended practice. In every case the first listed (letter A) describes recommended best practice.

(b) Different Methods for different kinds of construction are collected under one general heading and sub-numbered 1, 2, 3, etc., *without intent to indicate preference.*

(c) The arrangement of subjects has been made to agree, as nearly as possible, with the usual arrangement of sheet-metal specifications for the average building.

(d) When it is expedient to write a short specification to cover all the Sheet-Copper Work on a building Paragraphs 1 to 4 may be used. There should then be a definite understanding between the contracting parties about Alternate Methods.

1. General Conditions.

The General Conditions of the general contract are hereby made a part of this contract and this contractor shall examine these General Conditions and thoroughly acquaint himself with all the requirements therein contained that in any way affect his work.

2. Sheet-Copper Work.

Unless otherwise specified, all sheet-metal work, and all material and labor in connection therewith, shall be furnished and performed in strict compliance with the recommended practice and Standard Specifications for Sheet-Copper Work of the Copper & Brass Research Association, 420 Lexington Avenue, New York 17, N. Y.

Each bidder shall submit with his bid a list of the Alternate Methods, contained in these specifications, on which his bid is based.

3. Scope of Work.

Except as otherwise specified below this contract includes the furnishing of all labor and materials necessary to complete in every respect, in accordance with the best practice, all the Sheet-Copper work of every description for this building.

4. Work Not Included.

The following work is not included in this contract:

(List here any items to be omitted that usually are included in the sheet-metal contract, or that might be so considered if not specifically exempted.)

5. Guarantee.

Before final payment this contractor shall give to the owner a written guarantee which shall specify the kind, weight and manufacturer of the materials used, and shall guarantee the work free from all defects of workmanship for a period of .... years after completion. This contractor shall **(1)** make good all defects: and **(2)** pay for all damage to the building from leaks during that time.

6. Sheet Copper.

All sheets shall conform to A.S.T.M. Specification B-152, shall be rolled from copper conforming to A.S.T.M. Specification B-5, and shall be marked plainly with the manufacturer's name and the weight.

All sheet metal shown on the plans and not otherwise specified herein, shall be of 16-oz. cold-rolled copper.

Where specified elsewhere herein, all copper shall be soft (roofing temper) copper sheets.

7. Tolerances in Thickness.

Copper sheets shall meet the following minimum requirements for thickness:

Nominal Weight, Ounces	Nominal Thickness, Inches	Minimum Thickness, Inches
10	0.0135	0.0120
16	0.0216	0.0190
20	0.0270	0.0245
24	0.0323	0.0300
32	0.0431	0.0405

8. Lead-Coated Copper.

Where shown on the plans copper shall be lead-coated. The exact weight, texture, and tone of the lead coating on each side of the sheet shall be specified by the architect, in accordance with A.S.T.M. Specification B-101.

9. Crimped Copper.

Where specified, or shown on the plans, sheets shall be used that have been crimped to form ridges about 7/32-inch center to center in the direction of the short dimension.

10. Corrugated Copper.

Where called for on the plans corrugated copper of the form and gage specified shall be used.

11. Roofing Felt.

Roofing felt shall be felt or similar fibre mat saturated with asphalt or pitch and shall weigh not less than 14 lbs. per 108 square feet.

12. Building Paper.

Building paper shall be of a smooth unsaturated quality, rosin-sized, and shall weigh not less than 6 lbs. per 100 square feet, or 30 lbs. per standard roll of 500 square feet.

13. Tin.

All tin used for tinning seams, etc., shall be best grade, pure, new, block metal.

14. Solder.

All solder shall be of the best grade, equal to A.S.T.M. Specification B-32, and shall be composed of one-half pig lead and one-half block tin (new metals).

Where used on lead-coated copper, the composition shall be 60% lead and 40% block tin.

15. White Lead.

Where specified seams shall be caulked with white lead paste made up of basic lead carbonate, conforming to A.S.T.M. Specification D81-34, and boiled linseed oil. The oil shall make up 8% of the paste which shall be smooth, free from lumps, and of a putty-like consistency.

16. Elastic Cement.

Elastic cement shall be a mixture of asphalt and asbestos fibres, in conformance with the requirements of U. S. Federal Specification SS-C153.

17. Flux.

(A) Rosin, **(B)** muriatic acid killed with zinc, or **(C)** an approved brand of soldering paste, shall be used as a flux. After soldering any acid flux shall be washed off with a solution of soap and 5% to 10% washing soda.

18. Soldering Coppers.

All soldering shall be done with heavy soldering coppers of blunt design, properly tinned before use. They shall weigh not less than 6 lbs. to the pair, except that for flat-seam work they shall weigh not less than 10 lbs. to the pair.

19. Nails and Fastenings.

All nails, rivets, screws, expansion inserts, bolts and similar fastenings shall be of best grade hard copper or copper-alloy.

(1) Nails for wood sheathing and nailing concrete shall be flathead, barbed, wire slating nails not less than No. 12 gage and not less than 1″ long.

(2) For precast or poured gypsum nails shall be: **(1)** large flathead cut; **(2)** flathead wire slating, not less than No. 10 gage and not less than 2″ long.

(3) Screws and bolts shall have round heads rather than flat heads countersunk.

(4) Where shown on the drawings, or specified herein, fastenings shall consist of: **(1)** lead plugs one inch wide expanded into raked joints; **(2)** nails or round-headed bolts or screws driven into expansion inserts, or sleeves of sheet lead that have been inserted in holes drilled in the masonry. Screws shall be set through washers and soldered to the sheet.

20. Contractor to Examine Surfaces.

This contractor shall carefully examine all surfaces prepared for flashings, etc., by other trades, shall point out all defects, and shall see that the necessary corrections are made before proceeding with his work.

This contractor shall arrange his work so as to co-operate at all times with other trades and prevent delay or damage to other work.

All wood sheathing shall be absolutely dry and sound when copper is applied.

21. Preparation of Surfaces. (Other Contractors.)

All surfaces to receive flashings shall be made smooth and even, and free from all small projections or hollows, and all nail heads shall be set.

22. Precautions Against Damage During Construction.

During construction care shall be taken to prevent damage to sheet-copper work in place by walking or placing heavy materials thereon. As soon as soldering is done, the work shall be thoroughly cleaned. Toward completion, all damaged work shall be repaired, shall have all stains and debris removed, and shall be left in perfect condition.

23. Sheathing. (Carpenter's Specification.)

All wood sheathing upon which sheet copper is to be laid shall be of straight, unwarped boards: **(A)** *kiln-dried;* **(B)** *air-dried; free from splits and knot holes and impregnated to resist decay. All joints shall be true and even. All nail heads shall be set. All uneven edges of boards shall be smoothed off to give a firm, even surface.*

Notice shall be given to the roofing contractor when the sheathing is laid and an inspection shall be made by him. All defects observed at this inspection shall be corrected.

24. Concrete (Mason's Specification.)

All concrete surfaces to be covered with copper shall be made smooth and even with a wash of neat cement. Where cinders have been used in the concrete it shall be painted with two heavy coats of asphalt paint.

Where required, provision shall be made for securing copper work by means of: **(1)** *nailing into* **(A)** *nailing concrete;* **(B)** *embedded wooden battens;* **(2)** *expansion bolts.*

25. Gypsum. (Manufacturer's Specification.)

Gypsum surfaces to receive sheet copper shall be well-laid, smooth and even. Where nailing is required the gypsum shall be of sufficient thickness to allow a 2" penetration of copper-alloy nails.

26. Miscellaneous Laying Surfaces. (Manufacturer's or Mason's Specification.)

Where copper is to be laid on or against terra-cotta, stone, brick, or stucco, the surfaces shall be made smooth and even with a wash of neat cement, or two coats of heavy asphalt paint.

All inserts, anchors, nailing strips and similar fastenings for the copper, that may be required or indicated by the type of construction, shall be: **(1)** *provided and installed;* **(2)** *provided by others and installed by this contractor.*

27. Laying Building Paper.

Before laying copper all surfaces, except as specified below, shall be covered with roofing felt and rosin-sized paper placed in that order. Each ply shall lap 2" with the slope and shall be nailed with large flat-head copper or copper-alloy nails.

Nails in the roofing felt shall be driven through sheet copper washers spaced not more than 3" apart on all lapped seams. Nails in rosin-sized paper shall be spaced not more than 18" apart on all lapped seams.

On masonry surfaces where, because of the construction, conventional means of fastening are not feasible, rosin-sized paper, lapped as above, shall be affixed to the masonry with an adhesive, such as asphalt paint, applied every 12". Laps shall be sealed with asphalt paint.

Surfaces smoothed with asphalt paint shall be covered with rosin-sized paper, lapped as above, with laps sealed with asphalt paint.

28. Tinning.

(1) The edges of all sheets to be soldered shall be tinned 1½" on both sides with pure tin or solder. Rosin shall be used as a flux.

(2) Lead-coated copper shall not be tinned, but the lead surfaces in contact with solder shall be wire-brushed to produce a bright surface.

29. Soldering.

(1) Soldering shall be done slowly with well-heated coppers so as thoroughly to heat the seam and sweat the solder through its full width.

(2) When soldering lead-coated copper a liberal amount of flux shall be brushed into the seam.

30. Seams.

Standing seams shall finish not less than 1" high unless particularly specified otherwise.

Flat-lock seams shall finish not less than ½" wide.

Lap seams, where soldered and subject to stress, shall finish not less than 1" wide.

Lap seams, where soldered and not subject to stress, shall finish not less than ½" wide.

(*Continued on page 130*)

Lap seams not soldered shall lap with the roof slope not less than 3″.

Double- or copper-lock seams shall finish not less than ½″ wide.

All flat and lap seams shall be made in the direction of the flow.

31. Loose-Lock Seams.

Loose-lock seams shall be provided where shown on the plans. They shall be so formed and located as to preclude leakage.

32. Cross-Folded Loose Seams.

Where sheet copper is folded first in one direction and then at right angles thereto, as in the slip joints of base flashings, expansion joints, etc., the portion at the cross fold shall be slit and a patch of copper shall be soldered over the slit to prevent binding.

33. Exposed Edges.

Except where shown otherwise on the plans, or where it may be necessary to form a drip, the exposed edges of all flashings shall be doubled back ½″ in such manner as to conceal the folds from view.

34. Cleating and Fastening.

All pieces over 12″ wide shall be fastened by cleats 2″ wide and about 3″ long, spaced as specified elsewhere. They shall be secured to the roof by two nails set about ¾″ from the end and shall have the end turned back to cover the nail heads. The free end of the cleat shall be locked into the seam or folded edge of the piece. Where seams are soldered cleats shall be tinned. Except as otherwise specified cleats shall be of 16-oz. copper, spaced not more than 12″ apart.

Pieces up to 12″ wide shall be secured by nails placed along one edge only, and spaced not more than 4″ apart.

Where copper is to be laid on concrete or gypsum roof slabs, or over other masonry surfaces, this contractor shall prepare for the general contractor detailed instructions, with drawings, etc., for locating all fastenings for cleats, edge and eaves strips, flashings, etc.

35. Fastenings for Copper Roofing. (Mason's Specification.)

In all concrete, gypsum, or similar roof slabs that are to be covered with copper roofing or flashing, set fastenings for cleats, edge, and eaves strips, etc., as located by the sheet-metal contractor. Fastenings shall consist of **(1)** *2″ x 2″ nailing strips placed in the roof slab flush with the surface;* **(2)** *wood grounds placed in the roof slab at eaves, etc.;* **(3)** *expansion inserts to receive nails or screws.*

Before the roof slabs are poured this contractor shall obtain from the general contractor complete instructions, with drawings, for locating fastenings.

36. Batten Seam Roofing.

Wood battens of the shape and dimensions indicated shall be set under another contract to the spacing shown on the drawings. This contractor shall see that these are truly lined, evenly spaced, and well secured with all nails set, and bolts or nuts countersunk, and shall not proceed until all faults have been corrected.

Copper pans, made from sheets 96″ long, shall be placed between the battens, starting at the eave. Starting pans in alternate courses shall be 48″ long. Sides of sheets shall turn up to the height of the battens, plus ½″ to form a lock with the batten cap.

Sheets and caps shall be of 16-oz. copper, except that if sheets over 24″ wide are used to form pans they shall be of 20-oz. copper.

On roof slopes of 6″ or more to the foot cross seams shall be formed from a ¾″ fold (under) on the lower end and with a 2″ fold (over) on the upper end. The folds in the cross seams shall be slit at each corner, 1″ from the batten, to avoid a cross-folded seam. The tab resulting from the slit in the fold at the upper end shall be soldered to the vertical leg of the pan.

On roof slopes of less than 6″ to the foot cross seams shall be formed from ¾″ folds down the slope on both ends of the pans. A copper lock strip 1½″ wide shall be soldered to the upper fold and shall turn up on each vertical leg 1¼″. The lower edge of the lock strip shall be 3″ below the upper edge of the pan. The ¾″ fold in the lower end of the upper pan shall hook into the lock strip.

Cleats, spaced not more than 12″ on center, shall be nailed to the vertical sides of the battens. There shall be one cleat at the center of each cross seam.

All cross seams shall be flat-lock, and **(1)** unsoldered; **(2)** filled with white lead; **(3)** thoroughly sweated with solder, as specified under "Soldering."

Cover strips shall be placed over the battens. The edges shall lock with the ½″ horizontal flanges of the roof pans and be malleted down against the sides of the battens. Batten ends shall be covered with a cap folded and locked into the batten caps and vertical sides of the pans.

37. Battens or Ribs for Copper Roofing. (Carpenter's Specification.)

Where indicated on the drawings place on the roof sheathing wood battens or ribs shaped as detailed. The spacing of these ribs is approximately ...... inches. The

exact spacing shall be determined by the architect, and this contractor shall use a templet or gage-board to insure proper lining and spacing. They shall be firmly nailed with all nail heads set.

38. Battens or Ribs for Copper Roofing. (Concrete Contractor's Specification.)

Battens shall be secured to concrete roof decks by through bolts, or expansion bolts of the cinch type, and to gypsum decks by through bolts, spaced not more than 3′ 6″ on centers.

39. Standing Seam Roofing.

Seams shall be spaced as shown on the plans.

Sheets shall be 48″ or 96″ long. They shall be laid with long edges turned up to form standing seams, and shall be secured by cleats. No solder shall be used on standing seams. Cross seams shall be staggered.

The pan method may be used on slopes of 6″ or more to the foot. Pans shall be formed of sheets 48″ long turned up 1½″ on one long edge and 1¾″ on the other; a ¾″ fold (under) at the lower end; and a 2″ fold (over) on the upper end, so as to form loose locks when joined. The folds in the cross seams shall be slit in each corner, 1″ from the standing leg, to avoid cross-folded seams. The tab resulting from the slit in the upper end shall be soldered to the vertical leg.

On roof slopes of less than 6″ to the foot sheets 48″, or 96″, long shall be double-locked together in the shop to form a strip, or roll, equal to the length of the roof slope. Standing seams shall be formed at the job with roofing tongs.

All copper shall be 16-oz., except that if seams are spaced more than 20″ pans or rolls shall be of 20-oz. copper.

Cleats shall be spaced 12″ on centers in each standing seam. There shall be two cleats at each cross seam.

Standing seams shall finish 1″ high, except on curved roof surfaces where they shall finish ¾″ high. Ends of standing seams shall be: **(A)** folded over at an angle of 45°; **(B)** turned down in a tapered fold; **(C)** pinched tight and soldered.

40. Flat-Seam Roofing.

Roofing shall consist of 20-oz. rectangular sheets not larger than 16″ x 18″, laid in courses parallel with the eave, with the shorter dimension at right angles to the course, and with cross seams staggered. Edges of sheets shall be folded to form ¾″ flat seams locked in the direction of the flow. Corners shall be notched. There shall be 2 cleats of 20-oz. cold-rolled copper on the long and short side of each sheet. All seams shall be **(1)** malleted flat and soldered; **(2)** filled with white lead and malleted flat.

41. Corrugated Copper Roofing and Siding.

Corrugated sheets for roofing shall be of 20-oz., or heavier, and for siding at least 16-oz., copper. They shall have a side lap of at least one corrugation for siding, and 1½ or 2 corrugations for roofing. End laps of sheets shall be at least 3″ for siding and 6″ for roofing.

All fastenings shall be of copper or copper-alloy, and for roofing sheets they shall be applied through the high points of the corrugations.

When laid on steel purlins, the steel shall be insulated from the copper sheets by: **(A)** lead strips or washers; **(B)** asbestos strips; **(C)** heavy asphalt paint over steel.

42. Copper Shingles and Tile.

These units shall be applied as called for in the manufacturer's specifications.

43. Flashings—Where Required.

All intersections of roofs with vertical surfaces of every kind, and all openings in roof and wall surfaces, shall be flashed with copper. In addition flashings shall be installed wherever shown on the plans. The method of flashing, except as otherwise shown or specified, shall be base and counter, or cap, flashing.

44. Continuous Flashings.

Where the design or construction is such that the usual base and counter-flashing method is impracticable, flashings shall be made continuous from the roof surface up and into the vertical surface. Flashings of this type shall be made generally in two or more pieces, locked together by flat-lock seams filled with white lead or elastic cement. Lap seams shall be used where approved by the architect.

45. Size of Sheets for Flashings.

Base and counter (cap) flashings shall be of pieces not exceeding 96″ in length.

In general, flashings for flat surfaces such as decks, crickets, etc., shall be made with sheets not larger than 16″ x 24″.

Strip copper may be used for flashings up to 20″ wide.

46. Base Flashings.

Unless otherwise shown on the plans, base flashings shall be of not lighter than 16-oz. copper. They shall be

(Continued on page 132)

generally, 6" high, or shall extend up walls to within 1" of the counter flashing. They shall extend out on the roof at least 4", except as otherwise shown or specified.

Base flashings in excess of 10" wide shall be of 20-oz. copper.

Straight runs 24' long may be made up of 8' lengths joined with ¾" flat-lock soldered seams. These units shall be joined together by a 3" loose lock filled with white lead or elastic cement. Straight runs of less than 24' shall have a similar slip joint at the center.

There shall be a similar slip joint not more than 8' from any corner of the roof.

(1) The portion of the flashing in contact with built-up or composition roofing shall be given a coating of asphaltum paint before placing, and the outer edge shall be secured by copper nails spaced 3" apart.

(2) Base flashings on slopes covered with small-piece roofings such as shingles, slate, etc. shall be: **(A)** built in with each course, lapping the underlying piece at least 3"; **(B)** laid as specified by the manufacturer.

(3) Against stucco-coated walls, the metal lath shall lap outside the flashing so that the stucco shall finish over the flashing.

47. Counter or Cap Flashings.

Cap, or counter, flashings of 16-oz. copper shall be used on vertical walls in conjunction with base flashings, where impractical to use through wall flashings. They shall lap base flashings at least 4", have bottom edges folded under ½" and shall be creased longitudinally at the center of the exposed surface just enough to produce a spring action that will hold the bottom edges firmly against the base flashings.

Transverse joints shall be formed and filled as specified for base flashings.

Cap flashings shall be secured as follows:

(1) WOOD WORK. They shall extend under exterior coverings such as shingles, slate, etc., at least 2" above the butt of the second course, and in no case less than 4" above the roof.

(2) MASONRY (NON-MONOLITHIC). They shall extend into joints of masonry walls at least 2" and have the inner edge turned up or back on itself at least ¼". The sheets shall be bent to the required shapes, and built in with the masonry work. In existing walls, sheets shall be inserted not less than 2" into raked joints, and shall be secured with lead plugs 1" wide, 8" to 10" apart.

(3) REGLETS. They shall be secured, as specified below, in reglets cut in the masonry.

(4) STUCCO ON WOOD. They shall be formed over a base board or ground, extended up the wall at least 2", and be nailed at the top edge with nails about 8" apart. Metal lath shall be placed over the flashing and the stucco shall finish against the base board.

(5) STUCCO ON MASONRY. They shall be built into the masonry as the work progresses, shall project out from the wall as required, and turn down over the base flashing. The stucco shall finish against the cap flashing.

(6) CONCRETE WALLS. Copper reglets shall be set in the forms before the concrete is poured, into which the flashing shall be secured, as specified below, by lead wool set firm with a caulking iron.

48. Step Flashings.

Step flashings shall be used where slopes abut vertical surfaces.

They shall be formed of separate pieces built into the vertical surfaces as specified for cap flashings. Steps shall lap generally 3", but in no case less than 2", and shall not be soldered.

(1) Lap joints shall be vertical.

(2) Lap joints shall be normal to the roof slope.

49. Flashings. (Mason's Specification.)

Where shown on the plans, or specified herein, or elsewhere required by the architect, this contractor: **(1)** *shall do all the work necessary to install copper flashing pieces provided by the sheet-metal contractor and as directed by him;* **(2)** *shall prepare his work for the installation of flashings as directed by the sheet-metal contractor.*

50. Flashings for Clay and Cement Roof Tile.

Flashings of 24-oz. copper shall be laid as specified elsewhere for base, cap, and continuous flashings. All base flashings running with the length of the tile shall extend out on the roof under the tile as far as possible without puncture by nails, and shall be formed into a trough by turning up the edge 90°. So far as is possible flashings shall be laid to avoid sharp bends and angles, and shall not be nailed, but shall be held in place by the weight of the tile, or by cleats. The manufacturer's specifications shall be followed for flashings of special shapes, etc.

Exposed flashings shall extend with the length of the tiles at least 6" and shall be formed over them. Those extending crosswise shall terminate in depressions or locks and be held in place by the adjoining tiles, or by cleats.

Where vent pipes occur, the pieces of tiles fitted around them, after being bedded in mortar or secured with nails, shall be covered with flashings extending down the roof to the ends of the tile, out on the sides to the first lock or trough, and up the roof under the tiles over the wood battens, or to the nails securing the tiles.

Valley flashings shall be formed to fit the type of tile used and shall extend up the sides of the intersecting

slopes, or be turned over the supporting wood battens, to form a valley at least 2″ deep.

Flashings against the sides of dormers, etc., on sloping roofs shall continue as a trough under the tile and discharge out on top of the tile below, or into the gutter.

51. Flashings for Built-Up Roofing. (Roofer's Specification.)

Copper base flashings shall be not less than 8″ high and extend at least 4″ out on the roof in accordance with Specification No. 156 of the Federal Specification Board for the "Installation of Metal Flashings with Bituminous Built-up Roofings."

Cap-flashings shall be installed by the sheet-metal contractor as specified elsewhere. The roofing contractor shall read carefully the sheet-metal specifications.

52. Flashings for Terra-Cotta.

Where indicated on the drawings terra-cotta shall be flashed with 20-oz. copper. The top surfaces of all projections shall be completely flashed, and where shown on the plans all deck projections shall be flashed.

Flashings shall be secured by brass screws set with lead sleeves into holes formed in the terra-cotta. They shall extend down below the edge to form a drip.

53. Hips and Ridge Flashings.

(1) Install hip and ridge flashings of 16-oz. copper over roofing or battens set by other contractors. They shall be secured on either side of the roll by round-head brass wood-screws about 12″ apart, set through washers. Holes in the roof covering shall be drilled. The heads of the screws and washers shall be covered with copper caps soldered to the flashing.

(2) Copper hip and ridge rolls of design shown shall be installed over battens, etc., set by other contractors. The apron shall be held down by 3/16″ x 1″ brass bands 30″ apart, secured to the batten by brass wood-screws set through countersunk holes.

54. Open Valley Flashings.

(1) Open valley flashings shall be of copper generally of the weight specified by the manufacturer of the roofing material, but in no case less than 16-oz. They shall extend under the roof covering the distance specified by, and shall conform otherwise to, the specifications of said manufacturer.

(2) Open valleys shall be not less than 4″ wide. The proper width shall be determined by the following rule: Starting at the top with a width of 4″, increase the width 1″ for every 8′ of length of valley. Flashing pieces shall be full-length sheets, and of sufficient width to cover the open portion of the valley and extend up under the roof covering not less than 4″ on each side. The sheets shall not be punctured by nails.

There shall be no longitudinal seams in open valley flashings. The ends of sheets shall be: **(1)** lapped 6″ and left unsoldered; **(2)** formed into flat-locked seams; **(1)** filled with white lead; **(2)** soldered. Edges shall be turned back ½″ and held in place by cleats spaced not more than 12″ apart and nailed to the sheathing with two copper or copper-alloy nails.

(3) "FOLD-OVER" FLASHINGS shall be used, of such design as to allow not less than 3″ beyond the fold to be covered by the roofing. They shall be secured by cleats not more than 12″ apart.

(4) Where two valleys of unequal size come together, or where the areas drained by the valley are unequal, there shall be placed in the valley a "crimp," angle, or Tee, not less than 1″ high. This may be formed in the valley sheet before placing, or it may be made of a separate piece soldered to the valley sheet.

55. Closed Valley Flashings.

(1) Closed valley flashings shall be of copper generally the weight specified by the manufacturer of the roofing material, but in no case less than 16-oz. They shall be installed in conformance with the specifications of said manufacturer.

(2) BUILT-IN METHOD. Flashing pieces for closed valleys shall be of not lighter than 16-oz. sheet of sufficient length to extend to or above the top of the roofing piece and lap the flashing piece below 3″, and of width sufficient to extend up the sides of the valley far enough to make the valley 4″ deep. They shall be placed with the roofing so that all pieces are separated by a course of shingles or slate. Pieces shall be set so as to lap at least 3″ and to be concealed entirely by the roof covering. They shall be fastened by: **(1)** nails at the top edge only; **(2)** hooking over the tops of the underlying shingles.

(3) LARGE-PIECE METHOD. Before the roof covering is laid this contractor shall place in all valleys long strips of not lighter than 16-oz. copper of sufficient width to make a trough at least 4″ deep. These strips shall be laid from bottom to top of the valley with a 4″ lap, unsoldered. Where such strips are not over 12″ wide they shall be fastened with nails spaced every 18″ along the outer edge. Strips over 12″ wide shall be folded over ½″ along both edges and be fastened by 2″ cleats, spaced every 30″.

56. Changes of Slope.

All changes of slope on roofs covered with slate, tile or shingle roofings shall be flashed with copper, using the: **(1)** exposed; **(2)** concealed (mitred) method.

(*Continued on page 134*)

(1) EXPOSED FLASHINGS. On the upper slope flashings shall extend as far as possible without being punctured by nails, and be secured by cleats. On the lower slope they shall extend at least 3″ over the shingles.

(2) CONCEALED FLASHINGS. On the upper slope the construction shall be the same as for exposed flashings. On the lower slope the flashing sheet shall be carried down between the shingles of the double course to within ½″ of the butts. These shingles shall be fastened with countersunk brass screws passing through lead washers over the flashings.

57. Through-Wall Flashings.

Where called for in the specifications, or shown on plans, wall flashings shall be "through" flashings installed so as to provide a complete cut-off for seepage.

Flashings shall be of: **(A)** 16-oz. copper sheets; **(B)** weights as specified below; machine-formed with corrugations, ribs, ridges, bosses, crimps or stampings, singly or in combination, so as to assure a mechanical bond against lateral movement in all directions, and to provide free drainage of water outward. End joints shall be so lapped and locked that water will not leak through. Flashings at corners shall be one-piece.

The type of corrugations, etc., shall be approved by the architect. If a name brand is approved it shall be installed according to the manufacturer's specifications.

Flashings shall be placed as the work progresses, with a bed of mortar above and below. They shall extend the full thickness of the wall: **(1)** to within ½″ of the exterior face, with the outer edges bent up to turn seepage water back and in from the face; **(2)** to the outside with the outer edges bent down 45° to form drips.

Where dowels are used they shall penetrate the flashing and be made watertight as specified elsewhere.

(1) Under copings, at the base of parapet walls, and where the flashings extend beyond the wall to form cap flashings or to connect with other flashings or gutter linings, copper shall be 16-oz.

(2) Where entirely concealed in the masonry copper shall be 10-oz.

(3) Spandrels shall be flashed with not lighter than 6-oz. crimped copper.

(4) Spandrel flashings, and flashings around window and door openings, shall be done with an approved type of "copper membrane," an asphalt-impregnated building paper bonded to a 3-oz. layer of electrolytically-deposited sheet copper so as to form a single flexible sheet.

58. Flashings Between Old and New Work.

Where new work is to be flashed against old work, the flashing shall be such as to allow for settlement.

(1) Where the new wall is higher, the top of the old wall shall be covered with a flashing cap, extending completely over it and placed before the new wall is brought up. The old work shall then be flashed and counter-flashed to the new, the base flashing being turned down over the old wall and locked to the cap, and the counter flashing being built in with the new work as specified elsewhere.

(2) Where the new wall is lower, the joint shall then be flashed and counter-flashed, the base flashing extending down to form a cap over the new wall and locking to an edge, or nailing, strip. The counter flashing shall be set in a raked joint of, or reglet cut in, the old wall and secured as specified elsewhere.

(3) When the walls are level, the flashing shall consist of a cap continuous over both walls, properly sloped to shed water, and secured by brass wood-screws to the underside of a two-piece wood blocking secured on the walls by others. If over 24″ wide the flashing shall be in two pieces joined by a standing seam, or a loose-locked seam placed on one vertical side of the blocking so as to prevent leakage and to allow for settlement.

59. Water-Table Flashings.

Water-table flashings shall extend up the wall sheathing at least 4″.

(1) They shall be formed over the edge of the water table to make a drip and shall be secured at the upper edge by nails 4″ apart.

(2) If the edge strip method of fastening is used the upper edge shall be nailed about every 8″.

60. Drips and Edge Strips.

(1) Where indicated on the plans, flashings shall be secured by brass edge strips, ⅛″ thick by about 1¼″ wide. Strips shall be fastened to the vertical face of the projection by brass wood-screws in countersunk holes about 12″ apart, and set to allow the copper flashing to be hooked over the lower edge at least ⅜″.

(2) Where indicated on the plans, form drips of copper strips. These shall be nailed to the projection, shall project not more than ⅜″ below the sheathing or the upper fillet of the molding, and shall have the flashing hooked over the lower edge at least ⅜″.

61. Eaves Strips, and Gable Ends.

Install strips of 16-oz. copper along all eaves and roof edges except where gutters occur. They shall have a ½″ folded lower edge projecting ⅜″ below the sheathing or fillet of the molding to form a drip, and shall extend back on the roof 3″. They shall be installed in not exceeding 96″ lengths, with 2″ end laps, and shall be laid underneath the sheathing paper and nailed or cleated along the upper edge.

62. Gravel Stops.

Gravel stops shall be placed at the edges of all built-up roofs covered with slag or gravel. They shall be formed of one piece of 20-oz. copper to provide a ridge the full height of the roofing material at the outer edge. They shall project on the roof at least 4″, and be nailed on top of the roofing felt embedded in pitch, and covered with two layers of felt well mopped with pitch.

63. Eaves Troughs and Hangers.

Eaves troughs, or half-round hanging gutters, of 16-oz. copper, and of the size and type shown, shall be installed where shown on the drawings. They shall be in 10′ lengths and shall be joined by a 1″ lapped and soldered joint, or by slip joints.

All joints shall be made in the direction of the flow.

Eaves troughs shall be provided with end pieces, end caps, outlet tubes and mitres as required.

Eaves trough shall be supported by **(1)** wrought copper strap hangers of approved design; or **(2)** bronze or copper shank-and-circle-type hangers.

(1) Wrought strap hangers shall be spaced not more than 36″ apart and shall be secured to the roofing by brass screws, or copper nails.

(2) Shank-and-circle-type hangers shall be adjustable for slope and shall be spaced not more than 36″ apart. They shall be secured by brass screws.

64. Molded Gutters.

Molded gutters of the size and design shown, and formed of not lighter than 16-oz. copper, shall be installed where indicated on the drawings. **(1)** They shall have a flange extending up on the roof sheathing as far as possible without puncture by nails, and shall be held in place by cleats 30″ apart. **(2)** If impracticable to provide the flange, the gutter edge shall be locked to a flashing apron set as specified elsewhere.

Transverse joints shall lap 1½″ and be soldered. In gutters with bottom widths exceeding 6″, joints shall be riveted and soldered. Lengths of over 30′ shall be built with expansion joints, as specified elsewhere, placed: **(1)** at each end; **(2)** at the center point of the run.

Outlets shall be provided with tubes long enough to extend through the cornice and into the leader 3″.

(1) The outer edge of the gutter shall be stiffened by a brass rod or rectangular bar, and provided with a proper drip. Braces of heavy copper or brass, spaced 36″, shall be locked around or riveted to the outer edge, and secured to the roof sheathing above the flange or flashing by two brass screws.

(2) Gutters shall be secured by brass spikes driven into the rafter ends through copper spreaders, or sleeves, of proper width to maintain the shape of the gutters.

65. Linings for Molded Gutters.

Where indicated on the plans install gutter-linings of 16-oz. copper, shaped to fit the bottom of the gutter and sloped toward the outlet. All joints shall be lapped and soldered.

66. Pole Gutters.

Where indicated on the plans form gutters of 16-oz. copper over wood poles or strips set by the carpenter contractor. Linings shall turn down over the pole, and lock to a flashing strip secured to the outer face of the pole by cleats and extending out over the roof covering at least 4″.

Outlets shall be provided with tubes soldered to the lining and of length sufficient to extend 3″ into the leaders.

67. Built-In Gutter Linings.

Where indicated on the plans line all box or built-in gutters with .... oz. copper.

There shall be no longitudinal seams, and the cross seams shall be 36″ apart if the sectional contour of the gutter is more than 36″. If the sectional contour is 36″ or less, the gutter lining may be formed of copper sheets 8 feet in length.

Gutter linings constructed of 16- to 24-oz. copper shall have the ends joined together by ¾″ locked and soldered cross seams. For linings heavier than 24-oz., the ends shall be joined by 1½″ lapped, riveted and soldered cross seams. Rivets shall be of 3/16″ copper and spaced not more than 2″ on centers.

If the sectional contour of the gutter is more than 24″, the lining shall be held down by brass screws covered with 16-oz. copper cups soldered to the gutter lining. The screws shall be spaced not more than 36″ apart longitudinally and not more than 12″ apart transversely. Screws shall be No. 12 x ⅞″ roundhead brass screws where used in wood, and similar screws with expansion shields where used in stone. A brass washer, 1/16″ thick by 1¼″ in diameter, shall be provided under each screw head. The hole in the gutter lining shall be ¾″ and the screw shall be set at the center, except that holes opposite outlet tubes shall be the same size as the screws to provide anchorage to the gutter lining at these locations.

(1) The roof edge of the gutter lining shall extend under copper roofing not less than 6″ and terminate in a folded edge where it shall be secured by copper cleats spaced 24″. A continuous copper lock-strip, of the same thickness as the gutter lining, shall be continuously soldered to the gutter lining at the lower ends of the copper

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roofing sheets and the roofing copper shall connect to this lock strip with a loose lock.

(2) The roof edge of the gutter lining shall extend under slate, tile, or shingles not less than 6″ and terminate in a folded edge. A separate apron strip, not less than 6″ wide and formed of 16-oz. copper, shall be loose-locked into the folded edge of the lining. The upper edge of this apron shall be nailed to the roof boarding with copper nails spaced 4″ apart. Roofing nails shall not pierce the gutter lining.

A cant strip, formed of 16-oz. copper, 2″ wide and with a raised V, or ridge, at the center ½″ high, shall be tack-soldered to the lining at intervals of 6″ on each side.

At high parapet walls (over 24″) the outer edge of linings shall extend under cap flashings not less than 4″.

The outer edge of linings shall extend over the top of cornices or low parapets and shall be folded into a previously placed 32-oz. copper edge strip attached to wood construction with copper nails 4″ apart, and to stone with brass screws and expansion shields 12″ apart.

(1) Gutter linings in wood cornices shall have the front edges turned under the lower edge of a ⅛″ by 1¼″ brass strip screwed to the vertical face of the top member of the cornice. This strip shall be so placed as to form a proper drip.

(2) Gutter linings set in stone cornices shall be placed over a wood sheathing or nailing concrete forming the gutter slope. Outer edges shall be locked into a strip secured in a reglet. Where the wash slopes out and the width of the outer sheets of the lining exceeds 20″, a standing seam shall be formed at the reglet.

(3) Gutter linings in concrete or brick work shall be secured to batten nailing strips or nailing concrete, set by other contractors according to directions by this contractor.

(4) Gutter linings formed back of copper cornices shall have the front edge locked to the top edge of the cornice.

68. Built-In Gutters. (Carpenter's Specification.)

(1) *Form gutters as shown on the plans, and as directed by the architect, of ⅞″ T. and G. boards with nail heads set and all surfaces smooth. Consult with the sheet-metal contractor on all details in connection with his work.*

(2) *Set wood blocking and ⅞″ sheathing in masonry gutters as shown on the plans and directed by the architect to form backing for lining sloped to outlets. Make all surfaces smooth with nail heads set. Consult with the sheet-metal contractor on all details in connection with his work.*

69. Built-In Gutters. (Mason's Specification.)

Cut all reglets for gutter-linings as shown on plans or directed by the architect. Set all battens and nailing strips in masonry necessary for the sheet-metal work.

Form all depressions in masonry for outlet boxes as shown on the plans.

Form slopes to outlets in gutters and back of projections which are flashed.

All concrete surfaces to be covered with flashing shall be washed smooth with neat cement. Where cinders have been used in the concrete, surfaces shall be painted with two heavy coatings of asphalt paint.

Provide nailing concrete where called for in the drawings, with a smooth and even surface, and of required depth.

Consult with the sheet-metal contractor on all details in connection with his work.

70. Expansion Joints

(1) Gutters. Where called for on the plans provide expansion joints at high points, the full height of the gutters. The lining of the gutters shall be turned up and folded back to form flanges over which a 16-oz. copper cap shall be placed to form a watertight joint. There shall be sufficient play between the cap and the flanges to allow for the full movement of the gutter and the building. The cap shall have soldered on its outer edge a V-shaped curb to turn water from the roof into the gutter.

(2) Gutters. Expansion joints in gutters shall be provided midway between all outlet tubes, and where the ends of gutters abut masonry walls. The ends of each gutter section shall be closed with vertical pieces of 16-oz. copper, flanged, riveted and soldered to the lining. The top edges shall have horizontal flanges at least 1″ wide. There shall be an open space 1″ wide, or wider if necessary, to permit full movement of the gutters within the design-temperature range, between adjoining gutter ends, or between abutting walls and gutter ends. Cover strips, or caps, of 16-oz. copper, shall be loose-locked into the horizontal flanges of the gutter ends with sufficient play to permit full movement of the gutters in either direction.

Where the gutter ends abut masonry walls, cover strips shall extend up and under cap flashings built into the masonry.

The cover strips shall have V-shaped curbs to turn water from the roof into the gutter.

(3) Roofs. Expansion joints shall be formed on flat roofs as indicated on the plans. Roof curbs shall be covered with 20-oz. soft copper bent to form a V-ridge at the center, and shall be locked into top edge of base flashing, which shall be provided with the copper cleats spaced 12″ on centers. The V-ridge cover strip shall extend up the roof side of the parapet to the underside of the coping, shall extend across the top of the parapet wall with the V-ridge in a coping joint, and down on the outside to connect with the expansion fold in the exterior face of the wall.

The edges of the V-cover, where it extends up on the roof side of and over the top of the parapet, shall lock into 20-oz. soft copper cap-strips approximately 6″ wide. The outer edge of the cap-strips on the roof side shall lock into the masonry 4″ and terminate in a bent edge for anchorage. The cover strips shall have V-shaped curbs to shed water.

(4) Exterior Walls. Copper expansion folds shall be installed in exterior masonry walls where indicated on the plans. The units shall be formed of 16-oz. soft copper in 8′ lengths and shall run continuously from top of footing to top of wall. Joints shall lap 4″ in the direction of flow, and where they occur below grade the joints shall be soldered. Each flange of the unit shall be built into the masonry not less than 4″. The units shall be folded from copper 16″ wide and shall be in the form of a T with 3¾″ stem and with 4″ wings. Each wing shall have a ¼″ folded edge.

(5) Floors. Where expansion joints occur in floors, a 16-oz. soft copper water-stop shall be provided as shown. The copper shall extend into the concrete 3″ on each side of the expansion joints and shall have a loop at the joint to provide for expansion and contraction.

The joint at finished floor level shall be covered with a slip joint formed of brass angles and brass plates, and shall be anchored to the concrete with ¼″ brass anchors 2″ long, brazed to the brass angles and spaced 12″ on centers. The angles and plates shall be of design and dimensions shown on the drawings.

71. Outlets for Built-In Gutters.

Outlet boxes shall be formed as shown on the plans. The gutter lining shall be turned into them and soldered to the outlet tube.

Holes shall be cut as soon as the lining is placed and temporary spouts shall be used until the permanent system is ready.

Outlets shall be connected to leaders by:

(1) 32-oz. copper tubes with locked and soldered seams, and upper ends flanged, riveted and soldered to the outlet boxes. Tubes shall extend at least 3″ into the leaders;

(2) Seamless copper tubes soldered to the flanges of the outlet boxes and extending into leaders at least 3″;

(3) Copper tubes shall have soldered or brazed to them brass ferrules or caulking rings furnished by the plumbing contractor.

72. Roof Drains.

(1) Approved types of patented roof drains may be used. They shall be furnished and set by the trade having jurisdiction, and connections shall be made to them by the sheet-metal contractor in strict accordance with the manufacturer's directions.

(2) Roof drains shall consist of circular or square pans whose diameters or sides shall measure at least 4″ greater than the outlet, and have a depression of not less than 1½″. They shall have a flashing exending out on roof surfaces, on all sides of the pan, not less than 6″. The flashing or pan shall be provided with a rib forming a gravel stop or of proper height to receive: **(1)** built-up; **(2)** promenade-tile roofing.

(3) Roof drains shall consist of a copper flange extending out on the roof on all sides a distance at least equal to the size of the outlet. The flange shall be provided with a rib or gravel stop against which to finish: **(1)** built-up; **(2)** promenade-tile roofing.

73. Outlets from Roof Drains.

Outlets from drains shall consist of:

(1) a 20-oz. copper tube, soldered to the: **(A)** pan; **(B)** flange; and: **(1)** extending into the drain pipe at least 6″ with the outside coated with asphaltum paint; **(2)** with a brass ferrule or caulking ring soldered to the drain pipe by the plumbing contractor.

(2) a seamless copper tube, flanged at the top and soldered to the: **(A)** pan; **(B)** flange. Connections to the drain pipe shall be made by the plumbing contractor.

Where copper tubes connect firmly to drain pipes they shall be formed with horizontal circular corrugations or ribs to allow a bellows action under changes in length due to temperature or settlement.

74. Roof Drains and Gutter outlets. (Plumber's Specification.)

(1) *Furnish the sheet-metal contractor all brass ferrules necessary for connecting the drainage system and the roof drains and outlets shown on the plans, and connect copper tubes fitted with these ferrules to the drain pipes by caulked and leaded joints.*

(2) *Furnish and install complete with all piping connections the patent drains shown on the plans. Make provision, where necessary, for the work of other trades in connecting to the drains.*

(3) *Where shown on the plans furnish and install a seamless copper tube of a length necessary for the sheet-metal contractor to make a proper connection to the outlet-box or roof drain, and with a brass ferrule or caulking ring for connecting to the drain pipe.*

75. Strainers.

(1) All outlets from gutters and roofs shall be provided with heavy, cast brass, removable strainers the full size of the outlet box. The design and manufacturer shall be approved by the architect.

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(2) All gutter outlets shall be fitted with approved copper-wire strainers of the basket type, set in loosely.

(3) All gutter outlets shall be fitted with approved cast bronze strainers of the basket type, set in loosely.

76. Scuppers.

Flash all scuppers with copper, making same a part of the roof flashing. Flashings shall cover the interior completely and shall extend through and project outside of the wall. Seams shall be locked, or lapped, and soldered or brazed. Flashings shall be joined to roof flashings by soldered seams.

77. Scuppers. (Carpenter's or Mason's Specification.)

All enclosed roof surfaces shall be provided with scuppers or auxiliary drains. The bottoms of scuppers shall be not more than 2″ above the finished roof surface at the lowest point.

78. Auxiliary Drains.

Auxiliary drains shall be so constructed that their outlets are separate from and have openings at least 3″ above the main outlets.

79. Reglets.

Where indicated on the plans flashings shall finish in reglets in the masonry cut by others where located by this contractor.

A flashing strip, with edge turned back to form a hook, shall be turned into the reglet the full depth.

After the strip is in place it shall be secured by lead or soft copper plugs about 12″ apart, and caulked tight with molten lead on flat surfaces, and lead wool on vertical surfaces. After caulking, the reglet shall be made smooth by filling with elastic cement.

80. Reglets. (Mason's Specification.)

Where indicated on the drawings, or where directed by the architect, cut reglets in the masonry as located by the sheet-metal contractor for the insertion of flashings.

Reglets shall be ½″ wide at the top, ¾″ wide at the bottom, and 1″ deep. They shall be cut with true and straight edges, with sides and bottom roughened.

81. Flashings for Cornices, Balustrades, etc.

All masonry cornices, band courses projecting more than 12″, balconies, balustrades, etc., shall be flashed with copper. Flashings shall be secured on the outer edge by reglets. The back edge shall be continuous at least 3″ above the outer edge and in no case less than 4″ high. Where stone facing on brick backing is used, cap flashings shall be set in and shall cover the base flashings.

Where stone balustrades occur on top of a cornice, etc., flashings shall be set in reglets under the balusters, or shall be continuous through the balustrade and either turn down over the interior roof base-flashings as a cap flashing, or be connected thereto by a loose-locked joint. Dowels for fastening balustrade members shall penetrate the fastening and shall be covered with a copper cap or thimble, soldered to the flashing.

Flashings over 24″ wide shall have a full length soldered longitudinal seam, and shall have a standing seam at the reglet.

82. Curbs.

Curbs around roof openings shall have a flashing turned down on the inside about 3″ and secured with nails 1½″ apart. The flashing shall extend out on the roof as specified for base flashings.

83. Cricket or Saddle Flashings.

Crickets or saddles formed back of all vertical surfaces, such as chimneys, etc., breaking through sloping roofs, shall be covered with copper. The flashing of these crickets shall be made a part of the flashing along the sides of the chimney, etc.

84. Vent Flashings.

All pipes passing through roofs shall be flashed and counter-flashed. Base flashings shall extend out on the roof not less than ......″.

(1) They shall be of sufficient length to cover the roofing course next below and to extend up under the roofing course above as far as possible without puncture by nails.

(2) Where vent pipes extend more than 12″ above the roof the counter-flashing shall be caulked into the hubs or held with brass clamps embedded in elastic cement or white lead. It shall lap the base flashing at least 4″.

(3) Where the vent extends not more than 12″ above the roof surface it shall be flashed as follows:

Cast Iron Pipe. The base flashing shall be carried up to within 1″ of the top of the pipe and shall be counter-flashed by a copper cap 6″ high, turned over and down into the pipe at least 2″.

Threaded Pipe. The base flashing shall extend up to within 2″ of the end of the pipe, which shall be threaded. After the flashing is in place the threads shall be covered with white lead, and an iron or steel cap, of such design as to enclose the flashing material, shall be screwed onto the pipe.

(4) Patented vent-flashing devices may be used subject to the approval of the architect. They shall be made

of 20-oz. copper, shall be the product of a recognized manufacturer, and shall be installed according to said manufacturer's directions.

85. Ventilator Flashings.

Where metal ventilators are used on a roof they shall be connected to the flashing by soldered lap seams. The flashing sheet shall be the same weight as the ventilator flange, and shall extend out over the roofing on all sides at least ......".

(1) On shingle or slate roofs the flashing shall be secured by roundhead brass wood-screws set through holes drilled in the roof covering. The screws shall be set with slotted brass washers and shall be soldered to the flashing. The screws and screw holes shall be covered with soldered copper caps.

86. Rods and Dowel Flashings

(1) Where rods, etc., necessary to support balustrades or other architectural members, pass through flashings, joints shall be made tight as follows: the flashing pieces shall be punctured and set in position by sliding down over the rods; or, if this method is impracticable, the piece may be slit, fitted in place, and soldered. Cups, or thimbles, conforming to the shape of the rods, or bars, and at least 1" larger all around, shall then be placed around them and soldered to the sheets. These cups shall be filled with an approved waterproofing compound.

(2) Where dowels pass through flashings joints shall be made tight as follows: the flashing pieces shall be punctured and set in position over the dowels. Copper caps, just big enough to fit snugly and formed with a bottom flange, shall be fitted over the dowels and soldered to the flashings.

87. Guy-Anchor Flashings.

When bolts or similar devices penetrate sloping roof coverings, they shall be flashed as follows:

Before the courses above the bolt are laid, a piece of copper about 8" wide shall be placed over the lower roof covering and the sheathing, with the bolt projecting through a hole in the center. The sheet shall be of sufficient length to lap the first course below the bolts 4" and extend up and under the courses above as far as possible without puncture by nails.

The joint between the bolt and the sheet shall be closed by soldering to the sheet a flanged copper thimble placed around the bolt and caulked with waterproofing compound.

88. Flashing Around Steel Struts

Where steel struts, etc., penetrate a flat roof, a 20-oz. copper pan about 2" high above the finished roof level shall be formed around the member. It shall have a flange projecting out on top of the roofing at least 2". This flange shall be soldered to copper roofing, or, with built-up roofing, shall be covered with two layers of felt carried out on the roofing not less than 6" and well mopped with pitch. The pan so formed shall be filled with elastic cement or other waterproofing compound and the top surface sloped to drain freely.

On sloping roofs the procedure shall be the same except that the sides of the pan shall be built up level so as to retain the filler.

89. Flag Pole Flashings.

(A) Flag poles penetrating a flat roof shall have a 20-oz. copper circular base flashing extending up the pole at least 10" and 1" larger in diameter than the pole. It shall be turned out at the top. A 24-oz. copper conical hood, secured to the pole by a 1" brass band set in white lead and bolted, shall lap the base flashing at least 3".

(B) Patented flashing-flanges or similar devices for flashing flag poles shall be used subject to the approval of the architect. They shall be the product of a recognized manufacturer and shall have a flashing of 20-oz. copper. They shall be installed in accordance with the manufacturer's directions.

90. Window and Door Head Flashings.

Window and door frames set in frame construction shall have a flashing of 16-oz. copper over the head. This flashing shall be set after the frame is placed and shall be carried up the wall 2" above the butt of the second course of shingles, slate, etc., and in no case less than 3" above the window head. The bottom edge of the flashing shall be: **(A)** secured to the trim by an edge strip as specified elsewhere; **(B)** turned down over the trim so as to finish back of, and be secured by, the outside molding of the trim; **(C)** nailed at 1" intervals to the vertical face of the trim; **(D)** bent at a sharp angle to bear tightly against the top fillet of the molding: and the upper edge of the flashing, under the shingles, shall be secured by nails placed about 8" apart.

91. Window and Door Sill Flashings.

(1) Sill flashings of 16-oz. copper for window and door frames in frame construction shall be set before the frame is placed.

They shall extend to the back of the window sill and shall be nailed after the frame is set, and shall also extend out to the face wall.

(2) Wood sills set in stone or concrete shall have a strip of 20-oz. or heavier copper, or a bronze bar, at the joint. Just before setting the wood sill the reglet shall

(*Continued on page 140*)

be filled with waterproofing compound and the strip shall be embedded in it.

92. Window and Door Sill Flashings. (Carpenter's and Mason's Specifications.)

The sills of wood frames set in stone or concrete shall have a slot 1" deep to receive a copper or bronze flashing strip. Stone or concrete sills under wood window or door frames shall have a reglet cut or cast in them to receive a copper or bronze flashing strip.

93. Column-Cap Flashings.

The upper surfaces of all exposed column caps shall be flashed with 16-oz. copper. The flashing shall be formed to fit the cap and shall be turned down ½" over the edge of the cap and fastened with copper or copper-alloy nails. A separate piece shall be fitted over the dowel and soldered to the main flashing.

94. Column-Base Flashings.

Where shown on the plans bases of wood columns shall be flashed by a cap of 20-oz. copper made to fit the block used to hold the column. The cap shall have a flange extending out on all sides the necessary distance to provide for waterproofing, as specified elsewhere.

95. Scuttles.

Covers of roof scuttles shall be covered with copper. Sheets shall be laid with flat seams soldered, and shall be carried over the edge to the underside where they shall be secured with nails 1½" apart.

96. Skylights.

Where shown on the plans, build skylights of size indicated and of approved design and manufacture, with curbs at least 10" above the roof. All sheet metal shall be 20-oz. copper, reinforced where necessary for strength and stiffness with steel sections. Copper and steel shall be separated by coating the steel with asphalt paint, or by strips of lead. All sash bars and bearings for glass shall have condensation gutters leading to the outside. All skylights shall be made water- and weathertight with joints interlocked, riveted and soldered, and shall conform to the requirements of the National Board of Fire Underwriters. Duplicate sets of detail drawings shall be submitted for approval.

97. Louvres.

Where shown on the plans, louvres shall be formed of: **(A)** 24-oz. copper; **(B)** wood covered with 20-oz. copper.

Duplicate sets of detail drawings shall be submitted for approval.

98. Copper Cornices.

Where shown on the plans, cornices shall be made of .... oz. copper in strict accordance with the profiles, with moldings, true, sharp and straight. All flat surfaces over 5" wide shall be crimped, all mitres and joints carefully fitted, angles and corners reinforced, and all joints neatly riveted and soldered together and made watertight. Cornices shall be reinforced with properly-shaped heavy, copper-alloy brackets.

The top edge shall be formed over a heavy brass or bronze edge strip or drip properly shaped to permit the joining of the top flashing or gutter lining as specified elsewhere.

Ornaments shall be stamped in soft copper with dies made from approved models.

Duplicate sets of detail drawings shall be submitted for approval.

99. Copper-Covered Walls.

On vertical walls marked "Copper," such as bulk-heads, skylight curbs, penthouse walls, etc., erect standing seams or paneled surfaces as indicated. All standing seam work shall be of 20-oz. copper fastened to wall surfaces with cleats nailed to wood sheathing, or furring strips.

All paneled work shall be of 16-oz. copper and have casings or strips to receive copper. Crimped sheets shall be used for all large panels and large areas of plain surfaces.

Duplicate sets of detail drawings shall be submitted for approval.

100. Leaders, Conductors, or Downspouts.

Leaders of not lighter than 16-oz. copper shall be installed where shown on the plans, of the shapes and sizes indicated. They shall be held in position, clear of the wall, by

(1) Brass hooks, driven into the wall not more than 6' apart.

(2) Heavy brass or copper straps, ⅛" by 1½", spaced not more than 6' apart, soldered to the leaders, and fastened: **(1)** to wood work by brass screws; **(2)** to masonry by brass screws set in lead sleeves.

(3) Ornamental straps of: **(1)** stock design; **(2)** the design shown, and made of: **(1)** cold-rolled; **(2)** soft copper.

Leaders shall be in 10' lengths and shall have joints lapped. A 1½" slip joint shall be provided every 20' of leader.

There shall be a leader head, or similar device, to break the continuity of run, and to admit air, every 40′ of leader.

When leaders connect with underground drains they shall be fitted into drain-pipes, and shall have the joint neatly cemented. Those discharging at ground level shall have heavy shoes with reinforced ends.

101. Leader Heads.

Leader heads of: **(1)** stock design; **(2)** the design shown, shall be placed where indicated on the drawings. Outlet tubes from gutters shall extend into them 2″. The leader head outlet shall extend at least 2″ into the leader.

Large leader heads (12″ wide or over) shall have a heavy copper-wire removable screen over the top.

102. Snow Guards. (Roofer's Specification.)

(1) *Where shown on the plans furnish and erect on sloping roofs approved copper-wire snow guards spaced not more than 18″ apart in both directions and staggered.*

(2) *Where shown on the plans furnish and set at eaves approved adjustable pipe snow guards consisting of heavy brass pipe set with bronze supports.*

103. Insulation and Dampproofing.

Where shown on the plans, or specified elsewhere, a layer of an approved type of copper membrane, or asphalt-impregnated building paper bonded to 2-oz. sheet copper, shall be placed on:

(1) the outside face of all sheathing of wood frame construction, lapping 3″ in all directions, and attached with copper tacks;

(2) the exposed faces of roof rafters, lapping 3″ in all directions, and attached with copper tacks or nails;

(3) the lower slab of concrete floors, and held in place by an adhesive waterproofing compound. A vertical fold the full height of the upper slab shall form a cut-off dam at the walls. Laps shall be cemented with waterproofing compound;

(4) the footings over the foundation wall-key and up the outside face of the walls, being attached to vertical surfaces by an adhesive waterproofing compound. It shall be joined to the dampproofing course in the floor slab and shall terminate above grade in such manner as to provide a complete water seal.

104. Termite Shields.

Where shown on plans set termite shields formed as indicated of 16-oz. copper. Sheets shall not exceed 8′ in length and shall be joined by ¾″ lap joints soldered, or ½″ flat locks.

105. Cleaning Copper.

All copper work when finished shall be thoroughly cleaned of all flux, scraps and dirt. On large areas this shall be done as each section of the work is finished. Excess flux shall be neutralized by washing with: **(A)** a 5% to 10% solution of washing soda; **(B)** a solution of about one pound of lye in a pail of water. After cleaning the copper shall be washed off with clear water.

106. Coloring Copper.

All copper work to be colored shall be treated as prescribed by the Copper & Brass Research Association.

107. Painting Copper.

Copper shall first be thoroughly cleaned, free from dirt and grease, and absolutely dry. If possible the copper shall be permitted to weather through several rainstorms until the surface takes on a slight tarnish. Lead base paints shall be used for painting all copper work.

SECTION VII

MISCELLANEOUS DATA AND TABLES

PHYSICAL PROPERTIES OF ELECTROLYTIC TOUGH PITCH COPPER

A. GENERAL AND THERMAL

Specific Gravity	8.92
Density (Weight)	0.322 lb. per cu. in. at 68° F.
Thermal Conductivity	226 Btu. per sq. ft. per ft. per hr. per ° F. at 68° F.
Thermal Capacity (Specific Heat)	0.092 Btu. per lb. per ° F. at 68° F.
Coefficient of Thermal Expansion	0.0000098 per ° F. from 68° F. to 572° F.

B. MECHANICAL

(The following figures represent average values that may vary considerably in practice.)

Modulus of Elasticity (Tension)	17,000,000 p.s.i.
Tensile Strength	
Soft (Hot Rolled)	34,000 p.s.i.
Cold-Rolled (Hard)	36,000 p.s.i.
Yield Strength (0.5% Extension under Load)	
Soft (Hot Rolled)	10,000 p.s.i.
Cold-Rolled (Hard)	28,000 p.s.i.
Elongation in 2″	
Soft (Hot Rolled)	45%
Cold-Rolled (Hard)	30%
Shear Strength	
Soft (Hot Rolled)	23,000 p.s.i.
Cold-Rolled (Hard)	25,000 p.s.i.
Hardness—Rockwell (F Scale)	
Soft (Hot Rolled)	45
Cold-Rolled (Hard)	60

ACCEPTED TOLERANCE PRACTICE

1. SCOPE:

The practice set forth herein applies to both soft and cold-rolled copper sheet and strip.

2. THICKNESS TOLERANCES:

(a) For determining tolerances the thickness of copper sheets and strips for general sheet-metal purposes in building construction is taken as at 68 degrees Fahrenheit.

(b) For test of thickness micrometer readings are made on 10% of the sheets or strips in each case or crate lot.

(c) Each sheet or strip selected is gaged at evenly spaced points along both edges and in the center at both ends.

3. WEIGHT TOLERANCES:

(a) Weight tolerances of copper sheet or strip are determined by case or crate weight, normally approximately 500 pounds and not by single sheets or strips.

(b) All case and crate lots of copper sheet or strip rolled to weight, weigh as shown in Section C of Table I, on page 143.

TABLE I. STANDARD SIZES OF SHEET AND STRIP ROOFING COPPER

A. SHEET COPPER, SOFT AND COLD-ROLLED:

WEIGHT Ounces per Sq. Ft.	WIDTH in Inches			LENGTH in Inches
32	24	30	36	96
24	24	30	36	96
20	24	30	36	96
18	24	30	36	96
16	24	30	36	96, 120
14	24	30	36	96

NOTE—The above weights and sizes are generally preferred, but additional weights and sizes are available.

B. STRIP COPPER:

WEIGHT Ounces per Sq. Ft.	SIZE In Inches
32	20 x 96
24	20 x 96
20	20 x 96
18	20 x 96
16	20 x 120
16	20 x 96

WEIGHT Ounces per Sq. Ft.	SIZE in Inches
16	15 x 96
16	14 x 96
16	12 x 96
16	10 x 96
14	20 x 96
10	16 x 72

NOTE—The above weights and sizes are generally preferred, but additional weights and sizes are available. Strip is also generally available in rolls of 16-ounce copper in widths varying from 6" to 20" and from about 50 feet to 200 feet in length, depending on width, weighing between 80 and 100 pounds.

C. COPPER SHEET AND STRIP ROLLED TO WEIGHT, *including Strip Copper marked with Ounce Weights*

WEIGHT Ounces per Sq. Ft.	THEORETICAL THICKNESS in Inches	MINIMUM THICKNESS in Inches at any point	LOT WEIGHT TOLERANCES Based on Case or Crate Weight, normally approximately 500 lbs. Minimum	Maximum
32	.0431	.0405	95%	105%
24	.0323	.0300	95%	105%
20	.0270	.0245	95%	105%
18	.0243	.0225	95%	105%
16*	.0216	.0190	97%	103%
14*	.0189	.0160	97%	103%
10	.0135	.0120	95%	105%

Applicable to sheet and strip furnished flat up to 36" wide, inclusive, and up to 120" long, inclusive.

Thickness calculated for a unit weight of 0.322 pounds per cubic inch.

** 14- and 16-ounce strip copper is commonly stamped with the ounce weight.*

MATERIAL ESTIMATES FOR ROOFING

In estimating the amount of sheet copper required to cover a given roof area, the type of roofing, size of sheets, size of seams, and size and spacing of cleats must all be considered. To facilitate estimates the approximate quantities resulting from the commonly used sheet sizes in the three different types of copper roofing have been tabulated in Table II.

The first column gives the square feet of copper required to cover an area of 100 square feet. The figures are based on 2″ x 2″ tapered battens (page 35, Type B), 1-inch finished standing seams (page 19) and ¾-inch flat-lock seams (page 19).

The amount for cleats given in the second column assumes a spacing of 12 inches for batten and standing seam roofing, and two cleats on the long sides and two on the short sides of the sheets in the flat-seam construction, except for the 14″ x 20″ sheets where only one cleat is used on the short side. Cleats are assumed 2 inches.

The third column gives the total square feet of sheet copper required per roofing square. These totals can be used as percentages that, applied to the total square feet of roof to be covered, will give the square feet of copper required.

The last column gives the quantity of 1-inch nails required, assuming two nails per cleat and 292 nails per pound.

TABLE II. APPROXIMATE MATERIAL QUANTITIES *Per Roofing Square (100 Sq. Ft.)*

KIND OF ROOFING	COPPER SHEETS *Sq. Ft.*	COPPER CLEATS *Sq. Ft.*	TOTAL SHEET COPPER *Sq. Ft.*	1-INCH NAILS *Lbs.*
Batten seam—20″ x 96″ sheets	145	6	151	1
Batten seam—24″ x 96″ sheets	137	5	142	1
Batten seam—30″ x 96″ sheets	129	4	133	¾
Standing seam—20″ x 96″ sheets	123	4	127	⅔
Standing seam—24″ x 96″ sheets	119	3	122	½
Flat-seam—14″ x 20″ sheets	121	9	130	1⅓
Flat-seam—16″ x 18″ sheets	121	12	133	1⅔
Flat-seam—16″ x 20″ sheets	119	10	129	1½
Flat-seam—18″ x 24″ sheets	116	8	124	1

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